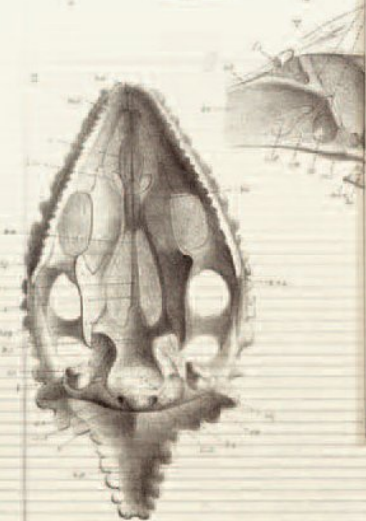
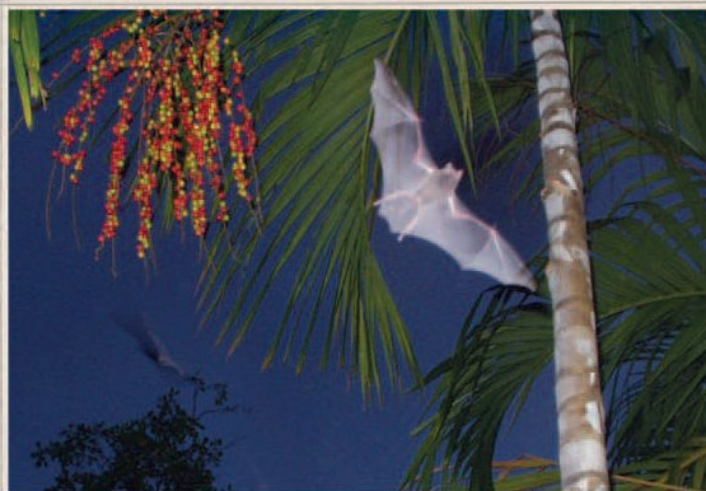


Phelsuma

Volume 12



Bird, St Denis
Praslin, Seychelle Arch
Nord, Nord
Africaines, Silhouette, Frigate
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Species list of marine molluscs on Silhouette island

GILL GERLACH & RON GERLACH

PO Box 207, Victoria, Mahé, SEYCHELLES
[npts@seychelles.net]

Abstract.—This paper presents a list of marine molluscs collected in 2000–4 from La Passe, Silhouette. 356 species are identified: 312 Gastropoda and 44 Bivalvia. 32 new records for the Seychelles islands, comprising *Turbo laetus*, *Eulima major*, *Cheilea papyracea*, *Cypraea obrelata*, *Cymatium labioscrum*, *Rapa bulbiformis*, *Coralliophila radula*, *Pyrene ocellata*, *Nassarius plicatus*, *Olivia tigrina*, *Olivia lepida*, *Mitra chrysalis*, *M. coarcta*, *Peristernia hilaris*, *M. floridula*, *M. isabella*, *M. picta*, *Cancilla carnicolora*, *Pterygia pudica*, *Swainsonia bicolor*, *Mitra rubritincta*, *Janthina globosa*, *Vexillum gorii*, *V. crocantum*, *V. speciosum*, *V. unifascialis*, *V. u. affinis*, *Conus retifer*, *Bullia ancillaeformis*, *Conus textilis*, *Barbista cf. foliata* and *Chlamys corruscans*.

Keywords.—Mollusca, Seychelles, Gastropoda, Bivalvia,

INTRODUCTION

A total of 356 mollusc species have so far been recorded from Silhouette: 312 Gastropoda and 44 Bivalvia. There are no records of marine molluscs collected on Silhouette prior to this collection made between 2000 and 2004. None of the molluscs appearing in this list have been taken alive, all were beach specimens collected after the construction of a small harbour at La Passe, other specimens were collected from the beaches of Anse Lascars and Grande Barbe.

Prior to the excavation into the reef flat to create the harbour, very few marine molluscs were found on the beaches of Silhouette and the majority of these were heavily calcified or bleached by the sun. The harbour was excavated to a depth of 6 metres below mean low water by a large mechanical digger which deposited the spoil in two protective breakwaters that form the sides of the harbour. From the spoil, numerous molluscs were collected, none containing the body of the mollusc and none still carrying the periostracum. Many specimens were in perfect condition despite the disturbance caused by the operations.

A large variety of molluscs continued to be washed onto the adjacent beaches for a period of about two years. Since then the marine environment appears to have stabilised and the number of specimens has returned to a seasonal norm.

Identifying and cataloguing the collection proved to be far more difficult than anticipated. The quality of photographs in the references is very variable and identifications often appear to contradict other references. Some references, such as JARRETT (2000), STEYN & LUSSI (1988) and OLIVER (1975) have accompanying descriptions, but others have only single photographs which do not help with the identification of variable species.

METHODS AND RESULTS

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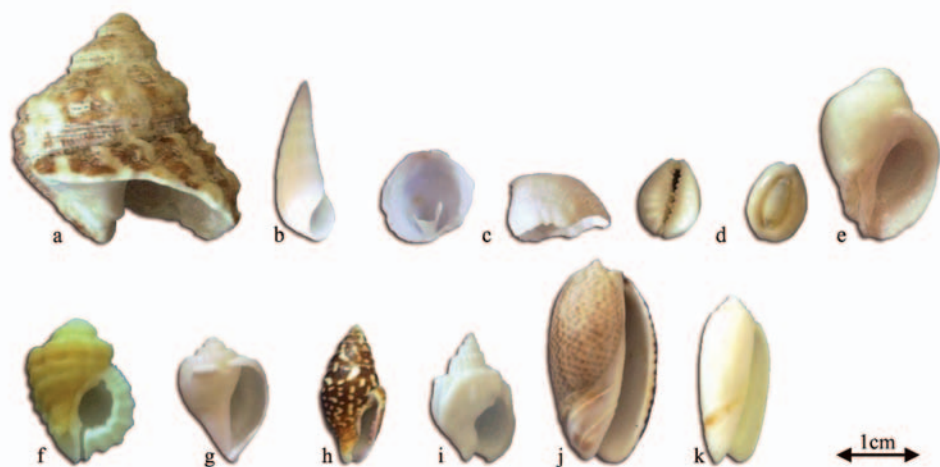


Fig. 1. a) *Turbo laetus*, b) *Eulima major*, c) *Cheilea papyracea* (ventral and lateral), d) *Cypraea obrelata* (dorsal and ventral), e) *Cymatium labioscrum*, f) *Rapa bulbiformis*, g) *Coralliophyla radula*, h) *Pyrene ocellata*, i) *Nassarius plicatus*, j) *Olivia tigrina*, k) *Olivia lepida*.

Annotated species list

Gastropoda

Patellidae

Cellana radiata BORN, 1778

Patella flexuosa QUOY & GAIMARD, 1834

There are also 2 unidentified *Patella* sp.

Fissurellidae

Diodora singaporensis REEVE

Trochidae

Clanculus flosculus FISCHER, 1878

Monodonata australis LAMARCK, 1818

Trochus maculatus LINNAEUS, 1758

Trochus mauritanus GMELIN, 1791

Trochus virgatus GMELIN, 1791

Stomatellidae

Stomatia irisata (DUFO, 1839)

Turbinidae	<i>Turbo argyrostomus</i> LINNAEUS, 1758 <i>Turbo brunneus</i> RÖDING, 1798 <i>Turbo laetus</i> PHILIPPI, 1850 - The first record for Seychelles <i>Turbo marmoratus</i> LINNAEUS, 1758 <i>Turbo petholatus</i> LINNAEUS, 1758 <i>Turbo setosus</i> GMELIN, 1791
Phasianellidae	<i>Phasianella aethiopica</i> PHILLIPI, 1853 There is a second, unidentified <i>Phasianella</i> species.
Neritidae	<i>Nerita albicilla</i> LINNAEUS, 1758 <i>Nerita plicata</i> LINNAEUS, 1758 <i>Nerita polita</i> LINNAEUS, 1758 <i>Nerita textilis</i> GMELIN, 1791
Neritopsidae	<i>Neritopsis radula</i> (LINNAEUS, 1758)
Littorinidae	<i>Littorina kraussi</i> (ROSEWATER, 1970) <i>Littorina (Littorinopsis) scabra</i> (LINNAEUS, 1758) <i>Littorina glabrata</i> PHILIPPI 1864 <i>Rissoina balteata</i> PEASE 1869 - recorded from Grande Barbe
Modulidae	<i>Modulus tectum</i> GMELIN, 1791
Planaxidae	<i>Planaxis niger</i> QUOY & GAIMARD, 1834 <i>Planaxis sulcatus</i> (BORN, 1780) A third <i>Planaxis</i> species is unidentified.
Vermitidae	<i>Dendromorpha thalia</i> KEEN & MORTON 1960 <i>Serpulorbis natalensis</i> (MORCH, 1862) <i>Vermisus</i> sp.
Cerithiidae	<i>Cerithium echinatum</i> LAMARCK, 1822 <i>Cerithium acutinodulosum</i> EA SMITH 1884 <i>Cerithium alveolus</i> HOMBRON & JAQUINOT 1854 <i>Cerithium citrinum</i> SOWERBY 1855 <i>Cerithium rostratum</i> SOWERBY 1855 <i>Cerithium tenuifilum</i> SOWERBY 1866 <i>Cerithium nodulosum</i> (BRUGUIERE, 1792) <i>Clypeomorus moniliferus</i> (KIENER, 1841) <i>Rhinoclavis aspera</i> (LINNAEUS, 1758) <i>Rhinoclavis fasciata</i> (BRUGUIERE, 1792) <i>Rhinoclavis kochi</i> (PHILIPPI, 1848) <i>Rhinoclavis sinensis</i> GMELIN, 1791
Hipponicidae	<i>Hipponix conica</i> SCHUMACHER, 1817
Eulimidae	<i>Eulima major</i> SOWERBY, 1834 - This is the first record for Seychelles <i>Melanella delecta</i> EA SMITH 1849 <i>Melanella cumingii</i> A ADAMS 1854
Vanikoridae	<i>Vanikoro cancellata</i> LAMARCK, 1822
Calyptreaeacea	<i>Cheilea equestris</i> LINNAEUS 1758 <i>Cheilea papyracea</i> REEVE, 1858 - This is the first record

	for Seychelles.
	<i>Cheilea tectumsinense</i> (LAMARCK, 1822)
Triphoridae	<i>Triphora corrugata</i> (HINDS, 1843)
Strombidae	<i>Strombus aurisdianae</i> LINNAEUS, 1758
	<i>Strombus decorus decorus</i> RÖDING, 1798
	<i>Strombus dentatus</i> LINNAEUS 1758
	<i>Strombus g. gibberulus</i> LINNAEUS, 1758
	<i>Strombus lentiginosus</i> LINNAEUS, 1758
	<i>Strombus mutabilis</i> SWAINSON, 1821
	<i>Strombus sinuatus</i> LIGHTFOOT 1786
Lambidae	<i>Lambis chiragra</i> (LINNAEUS, 1758) <i>arthritica</i> (RÖDING, 1798)
	<i>Lambis c. crocata</i> LINK, 1807
	<i>Lambis t. truncata</i> HUMPHREY, 1786
Lamellariidae	<i>Trivia oryza</i> LAMARCK, 1810
Ovulidae	<i>Calpurnus l. lacteus</i> LAMARCK 1810
	<i>Calpurnus verrucosus</i> LINNAEUS 1758
	<i>Ovula ovum</i> LINNAEUS, 1758
Cypraeidae	<i>Cypraea annulus</i> LINNAEUS, 1758
	<i>Cypraea arabica</i> LINNAEUS, 1758
	<i>Cypraea argus</i> LINNAEUS, 1758
	<i>Cypraea asellus</i> LINNAEUS, 1758
	<i>Cypraea caputserpentis</i> LINNAEUS, 1758
	<i>Cypraea carneola</i> LINNAEUS, 1758
	<i>Cypraea caurica</i> LINNAEUS, 1758
	<i>Cypraea cicerula</i> LINNAEUS, 1758
	<i>Cypraea clandestina</i> LINNAEUS 1767
	<i>Cypraea cribraria</i> LINNAEUS 1758
	<i>Cypraea depressa</i> GRAY 1824
	<i>Cypraea erosa</i> LINNAEUS, 1758
	<i>Cypraea feliina</i> GMELIN, 1791
	<i>Cypraea fimbriata</i> GMELIN, 1791
	<i>Cypraea globulus</i> LINNAEUS, 1758
	<i>Cypraea helvola</i> LINNAEUS, 1758
	<i>Cypraea hirundo</i> LINNAEUS, 1758
	<i>Cypraea histrio</i> GMELIN, 1791
	<i>Cypraea isabella</i> LINNAEUS, 1758 - This is the first record for Seychelles.
	<i>Cypraea kieneri</i> HIDALGO, 1906
	<i>Cypraea limacina</i> LAMARCK 1810
	<i>Cypraea lynx</i> LINNAEUS, 1758
	<i>Cypraea mappa</i> LINNAEUS, 1758
	<i>Cypraea mauritiana</i> LINNAEUS, 1758
	<i>Cypraea moneta</i> LINNAEUS, 1758
	<i>Cypraea nucleus</i> LINNAEUS, 1758
	<i>Cypraea obvelata</i> LAMARCK 1810- This is the first re-

- cord for Seychelles possibly a subspecies of *C. annulus* (ABBOTT & DANCE 1998)
- Cypraea poraria* LINNAEUS, 1758
Cypraea punctata LINNAEUS, 1758
Cypraea scurra GMELIN, 1791
Cypraea staphylaea LINNAEUS, 1758
Cypraea stolidia LINNAEUS, 1758
Cypraea talpa LINNAEUS, 1758
Cypraea teres GMELIN, 1791
Cypraea testudinaria LINNAEUS, 1758
Cypraea tigris LINNAEUS, 1758
Cypraea vitellus LINNAEUS, 1758
Cypraea ziczac LINNAEUS, 1758
- Naticidae
Natica lemniscata (PHILIPPI, 1851)
Natica onca RÖDING, 1798
Eunatica papilla GMELIN 1791
Polinices melanostomus GMELIN, 1791
Polinices tumidus SWAINSON, 1840
Sinum planulatum (RECUZ, 1845)
- Cassidae
Casmaria e. erinaceus LINNAEUS 1758
Casmaria ponderosa (GMELIN, 1791)
Cypraecassis rufa LINNAEUS, 1758
- Tonnidae
Malea pomum LINNAEUS, 1758
Tonna allium (DILLWYN, 1817)
Tonna cepa (RÖDING, 1798)
Tonna perdix LINNAEUS, 1758
- Ficidae
Ficus ficoides LAMARCK, 1822
- Cymatiaceae
Charonia tritonus LINNAEUS, 1758
Cymatium gallinago REEVE, 1844
Cymatium hepaticum RÖDING, 1798
Cymatium labiosum (WOOD, 1828) - This is the first record for Seychelles.
Cymatium lotorium LINNAEUS, 1758
Cymatium nicobaricum RÖDING, 1798
Cymatium pileare LINNAEUS, 1758
Cymatium vespacum LAMARCK, 1822
Distorsio anus LINNAEUS, 1758
Gyrineum pusillum (BRODERIP, 1833)
- Bursidae
Bursa bufo LINNAEUS, 1758
Bursa bufonia GMELIN, 1791
Bursa granularis RÖDING, 1798
Bursa rosa PERRY, 1811
- Muricidae
Chicoreus brunneus LINK, 1807
Chicoreus ramosus LINNAEUS, 1758
Chicoreus torrefactus SOWERBY, 1841
Homalocantha martineta RÖDING, 1798

- Thiadinae
- Murex tribulus* LINNAEUS, 1758
Pterynotus tripterus BORN, 1778
Drupina lobata BLAINVILLE, 1832
Drupa morum RÖDING, 1798
Drupa ricinus LINNAEUS, 1758
Drupella cornus RÖDING, 1798
Drupella fenestrata BLAINVILLE, 1832
Drupa rubusidaeus RÖDING, 1798
Drupella rugosa BORN, 1778
Mancinella echinulata LAMARCK, 1822
Mancinella tuberosa RÖDING, 1798
Nassa francolina BRUGUIÈRE, 1789
Morula biconica BLAINVILLE 1832
Morula granulata DUCLOS, 1832
Morula margariticola BRODERIP, 1832
Morula marginatrum BLAINVILLE, 1832
Morula uva RÖDING, 1798
Rapana rapiformis BORN, 1778
Thais armigera LINK, 1807
Thais bufo LAMARCK, 1822
Thais rudolphi LAMARCK, 1822
- Magilidae -
 (Coralliophilidae)
- Coralliophila costularis* LAMARCK, 1816
Coralliophila erosa RÖDING, 1798
Coralliophila monodonta BLAINVILLE, 1832
Coralliophila radula ADAMS, 1855 - This is the first record for Seychelles.
Coralliophila violacea KIENER, 1836
Rapa bulbiformis SOWERBY, 1870 - This is the first record for Seychelles.
Rapa rapa LINNAEUS, 1758
- Buccinidae
- Cantharus fumosus* DILLWYN, 1817
Cantharus undosus LINNAEUS, 1758
Cliviopollia fragraria WOOD, 1828
Engina alveolata KIENER, 1836
Engina bonasia MARTENS, 1880
Engina incarnata DESHAYES, 1834
Engina lineata REEVE, 1846
Engina mendicaria LINNAEUS, 1758
Engina zea MELVILL, 1893
Pisania gracilis REEVE, 1846
Pisania ignea GMELIN, 1791
- Columbellidae
- Columbella turturina* LAMARCK, 1822
Mitrella albina KIENER, 1841
Pyrene flava BRUGUIÈRE, 1789
Pyrene ocellata (LINK, 1807) - This is the first record for Seychelles.

Nassariidae

Bullia ancillaeformis SMITH, 1906 - This is the first record for Seychelles.

Nassarius arcularia plicatus RÖDING, 1798 - This is the first record for Seychelles.

Nassarius comptus ADAMS, 1852 *polita* (Marrat, 1880)

Nassarius coronatus BRUGUIERE, 1798

Nassarius elegans KIENER

Nassarius gemmulatus LAMARCK

Nassarius pauperus GOULD, 1850

Fascioliariidae

Latirus craticulatus LINNAEUS, 1758

Latirus polygonus LINNAEUS, 1758

Latirus smaragdulus LINNAEUS, 1758

Pleuroplaca filamentosa RÖDING, 1798

Pleuroplaca trapezium LINNAEUS, 1758

Peristernia nassatula LAMARCK, 1822

Peristernia hilaris MELVILL, 1891 - This is the first record for Seychelles.

Colubrariidae

Colubraria nitidula SOWERBY, 1833

Colubraria tortuosa REEVE, 1844

Olividae

Oliva annulata GMELIN 1791

Oliva bulbosa RÖDING, 1798

Oliva caerulea RÖDING, 1798

Oliva lepida (DUCLOS, 1835) - This is the first record for Seychelles.

Oliva panniculata DUCLOS, 1835

Oliva ponderosa DUCLOS, 1835

Olivis sidella DUCLOS, 1835 var. *valvaroides* DUCLOS, 1835

Oliva tigrina LAMARCK, 1811 - This is the first record for Seychelles.

Oliva tremulina (RÖDING, 1798)

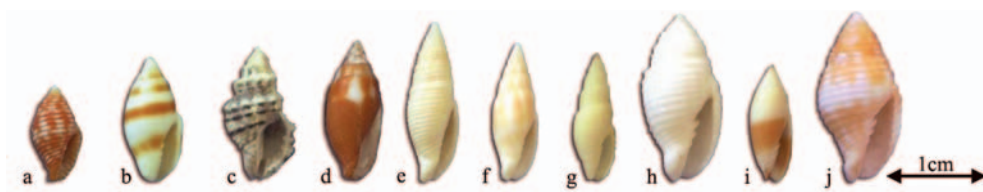


Fig. 2. a) *Mitra chrysalis*, b) *M. coarcta*, c) *Peristernia hilaris*, d) *M. floridula*, e) *M. isabella*, f) *M. picta*, g) *Cancilla carnicolora*, h) *Pterygia pudica*, i) *Swainsonia bicolor*, j) *Mitra rubritincta*.

Mitridae

Cancilla (Domiporta) carnicolor REEVE, 1844 - This is the first record for Seychelles.

Cronia crassulnata HEDLEY 1915

Mitra acuminata SWAINSON, 1824

- Mitra aurantia* GMELIN, 1791
Mitra chrysalis REEVE, 1844 - This is the first record for Seychelles.
Mitra chrysostoma BRODERIP, 1836
Mitra coarctata REEVE, 1844 - This is the first record for Seychelles.
Mitra coronata LAMARCK, 1811
Mitra cucumerina LAMARCK, 1811
Mitra edentula SWAINSON, 1823
Mitra fastigium REEVE, 1845
Mitra ferruginea LAMARCK, 1811
Mitra floridula SOWERBY, 1874 - This is the first record for Seychelles.
Mitra imperialis RÖDING, 1798
Mitra incompta LIGHTFOOT, 1786
Mitra isabella (SWAINSON, 1814)
Mitra luctuosa ADAMS, 1853
Mitra mitra LINNAEUS, 1758
Mitra picta REEVE, 1844 - This is the first record for Seychelles.
Mitra rubritincta REEVE, 1855 - This is the first record for Seychelles.
Mitra tabanula LAMARCK, 1811
Mitra (Nebularia) aurantia limbifera (LAMARCK, 1811) - There is considerable taxonomic uncertainty over this taxon, with populations elsewhere being identified variously as *M. aurantia*, *M. limbifera*, *M. telescopium* REEVE, 1844 or *M. scutulata* (GMELIN, 1791). A full revision is needed.
Mitra (Nebularia) vexillum REEVE, 1844
Pterygia pudica (PEASE, 1860) - This is the first record for Seychelles.
Strigatella acuminata (SWAINSON, 1824)
Strigatella litterata (LAMARCK, 1811)
Strigatella paupercula LINNAEUS, 1758
Strigatella ticaonica REEVE, 1844
Swainsonia bicolor (SWAINSON, 1824) - This is the first record for Seychelles. Referred to as *Scabricola bicolor* by DRIVAS & JAY (2001)
Pusia pardalis KUESTER, 1839
Vexillum gorii TURNER, 1996 - This is the first record for Seychelles.
Vexillum crocantum (LAMARCK, 1881) - This is the first record for Seychelles.
Vexillum sanguisugum LINNAEUS, 1758
Vexillum speciosum (REEVE, 1844) - This is the first re-

Costellariidae

Marginellidae
 Harpidae
 Vasidae

cord for Seychelles.

Vexillum u. unifascialis LAMARCK, 1811 - This is the first record for Seychelles.

Vexillum unifascialis affinis (REEVE, 1844) - This is the first record for Seychelles.

Marginella mazagonica MELVILL, 1893

Harpa armouretta RÖDING, 1798

Harpa major RÖDING, 1798

Vasum ceramicum LINNAEUS, 1758

Vasum turbinellus LINNAEUS, 1758



Fig. 3. a) *Vexillum gorii*, b) *V. crocantum*, c) *V. speciosum*, d) *V. unifascialis*, e) *V. u. affinis*, f) *Conus retifer*, g) *Bullia ancillaeformis*, h) *Conus textilis*.

Conidae

Conus arenatus HWASS, 1792

Conus aulicus LINNAEUS, 1758

Conus auricomus HWASS, 1792

Conus betulinus LINNAEUS, 1758

Conus canonicus HWASS, 1792

Conus capitaneus LINNAEUS, 1758

Conus catus HWASS, 1792

Conus chaldeus RÖDING, 1798

Conus coronatus GMELIN, 1791

Conus ebraeus LINNAEUS, 1758

- Conus episcopus* HWASS, 1792
Conus figulinus LINNAEUS, 1758
Conus flavidus LAMARCK, 1810
Conus fulgetrum SOWERBY, 1834
Conus geographus LINNAEUS, 1758
Conus gubernator HWASS, 1792
Conus imperialis LINNAEUS, 1758
Conus legatus LAMARCK, 1810
Conus leopardus RÖDING, 1798
Conus lividus HWASS, 1792
Conus litoglyphus HWASS, 1792
Conus luteus SOWERBY, 1833
Conus marmoreus (f. *bandanus*) LINNAEUS, 1758
Conus miles LINNAEUS, 1758
Conus nussatella LINNAEUS, 1758
Conus musicus HWASS, 1792
Conus namocanus HWASS, 1792
Conus obscurus SOWERBY, 1833
Conus rattus HWASS, 1792
Conus retifer MENKE, 1829 - This is the first record for Seychelles.
Conus sponsalis HWASS, 1792
Conus striatellus LINK, 1807
Conus tendineus HWASS, 1792
Conus tenuistriatus SOWERBY, 1858
Conus tessulatus BORN, 1778
Conus textilis LINNAEUS, 1758 - This is the first record for Seychelles.
Conus tulipa LINNAEUS, 1758
Conus varius LINNAEUS, 1758
Conus vexillum GMELIN, 1791
Conus zeylanicus GMELIN, 1791
Hastula albula MENKE, 1843
Hastula strigilata LINNAEUS (f. *verreauxi* DESHAYES)
Terebra affinis GRAY, 1834
Terebra areolata (LINK, 1807)
Terebra argus HINDS, 1844
Terebra cerithina LAMARCK, 1822
Terebra crenulata LINNAEUS, 1758
Terebra dimidiata LINNAEUS, 1758
Terebra felina (DILLWYN, 1817)
Terebra guttata RÖDING, 1798
Terebra hectica LINNAEUS, 1758
Terebra laevigata QUOY & GAIMARD
Terebra maculata LINNAEUS, 1758
Terebra nodularis DESHAYES, 1859

Terebridae

	<i>Terebra subulata</i> LINNAEUS, 1758
	<i>Terebra textilis</i> HINDS, 1844
Turridae	<i>Clavus exasperatus</i> REEVE, 1843
	<i>Paradrilla patruelis</i> (SMITH, 1875)
	<i>Tritonturris cumingii</i> (POWIS, 1823)
	<i>Turridrupa cincta</i> LAMARCK, 1822
Architectonicidae	<i>Heliacus infundibulformis</i> GMELIN, 1791
	<i>Heliacus trochoides</i> DESHAYES, 1830
	<i>Heliacus variegatus</i> GMELIN, 1791
Epitoniidae	<i>Epitonium jomardi</i> AUDOUIN, 1826
	<i>Epitonium varicosum</i> LAMARCK, 1822
Janthinidae	<i>Janthina janthina</i> LINNAEUS, 1758 - Only this species has been recorded on Silhouette. A specimen of <i>J. globosa</i> SWAINSON, 1822 was present in Betty Beckett's collection, this is the first record from Seychelles.
Bullidae	<i>Bulla ampulla</i> LINNAEUS, 1758
Hydatinidae	<i>Hydatina physis</i> LINNAEUS, 1758
Atyidae	<i>Atys naucum</i> LINNAEUS, 1758



Fig. 4. a) *Barbatia* cf. *foliata*, b) *Chlamys corruscans*, c) *Janthina globosa*.

Pyramidellidae	<i>Otopleura mitralis</i> ADAMS, 1854
	<i>Pyramidella sulcata</i> ADAMS, 1854
Siphonariidae	<i>Siphonaria atra</i> QUOY & GAIMARD, 1833
Bivalvia	
Arcaidae	<i>Andara</i> spp. - Two unidentified species have been collected.
	<i>Barbatia</i> cf. <i>foliata</i> (FORSKAL, 1775)
	<i>Barbatia fusca</i> BRUGUIÈRE, 1789
	<i>Barbatia helblingi</i> BRUGUIÈRE, 1792
	<i>Barbatia lacerata</i> BRUGUIÈRE, 1792
Mytilidae	<i>Brachyodontes variabilis</i> KRAUSS, 1848
	<i>Modiolus auriculatus</i> KRAUSS, 1848
	<i>Septifer bilocularis</i> LINNAEUS, 1758
Pinnidae	<i>Pinna muricata</i> LINNAEUS, 1758

	<i>Streptopinna saccata</i> LINNAEUS, 1758
Pteriidae	<i>Pinctada margaritifera</i> LINNAEUS, 1758 - A second, unidentified <i>Pinctada</i> species has been collected.
Pectinidae	<i>Chlamys coruscans</i> (HINDS, 1845) <i>Chlamys cf lemniscata</i> REEVE, 1853 <i>Chlamys senatorius</i> GMELIN, 1791 <i>Pecten</i> sp. <i>Semipallium tigris</i> LAMARCK, 1819
Ostreidae	<i>Lopha cristagalli</i> LINNAEUS, 1758
Spondylidae	<i>Spondylus hystrix</i> RÖDING, 1798
Chamidae	<i>Chama aspersa</i> REEVE, 1853 <i>Chama lazarus</i> LINNAEUS, 1758 <i>Chama cf limbula</i> LAMARCK, 1819 - A further six unidentified <i>Chama</i> species have been collected.
Lucinidae	<i>Codakia interrupta</i> LAMARCK, 1822 <i>Codakia punctata</i> LINNAEUS, 1758 <i>Codakia tigerina</i> LINNAEUS, 1758 <i>Divaricella ornata</i> REEVE, 1853 <i>Anodontia edentula</i> (LINNAEUS, 1758)
Cardiidae	<i>Cardita variegata</i> BRUGUIERE, 1792 <i>Fragum fragum</i> LINNAEUS, 1758 <i>Laevicardium australe</i> SOWERBY, 1834 <i>Trachicardium elongatum</i> BRUGUIERE 1789 <i>Trachicardium flavum</i> LINNAEUS, 1758
Tridacnidae	<i>Tridacna maxima</i> RÖDING, 1798 <i>Tridacna squamosa</i> LAMARCK, 1819
Mesodesmatidae	<i>Atactodea glabrata</i> GMELIN, 1791
Donacidae	<i>Donax cuneatus</i> LINNAEUS, 1758
Cultellidae	<i>Siliqua</i> sp.
Tellinidae	<i>Quidnipagus palatum</i> (IREDALE, 1829) <i>Tellina scobinata</i> LINNAEUS, 1758
Psammobiidae	<i>Asaphis deflorata</i> LINNAEUS, 1758
Trapeziidae	<i>Trapezium oblongum</i> LINNAEUS, 1758
Veneridae	<i>Australodosinia histrio</i> GMELIN, 1791 <i>Callista erycina</i> LINNAEUS, 1758 <i>Gafrarium dispar</i> (DILLWYN, 1817) <i>Gafrarium pectinatum</i> LINNAEUS, 1758 <i>Periglypta reticulata</i> LINNAEUS, 1758 <i>Tapes litteratus</i> LINNAEUS, 1758
Cephalopoda	
Spirulidae	<i>Spirula spirula</i> LINNAEUS, 1758
Other cephalopods observed around Silhouette include <i>Sepioteuthis lessoniana</i> FÉRUS-SAC, 1830 (Loliginidae)	

A preliminary vertebrate palaeontological survey of the granitic Seychelles islands

JULIAN PENDER HUME

Bird Group, Department of Zoology
The Natural History Museum
Akeman St, Tring, Herts HP23 6AP, U.K.

Palaeobiology Research Group
Department of Earth & Environmental Sciences
University of Portsmouth
Portsmouth, Hants PO1 3QL, U.K.

Abstract.— The results of a reconnaissance palaeontological survey are described, with an island by island review of potential fossil localities within the granitic Seychelles. Lowland/montane marsh and cave (boulder field) localities were examined, test pits dug on all sites and details recorded. The first giant tortoise and avian fossil material within the granitic Seychelles was discovered, although in general the localities were poor in both vertebrate remains and preservation quality.

Keywords.— cave, fossil, marsh, terrestrial snail

INTRODUCTION

The granitic Seychelles comprise 41 islands and islets situated between 4-5°S and 55-56°E (STODDART 1984). The islands are isolated, lying 930km from Madagascar to the southwest, 1590km from East Africa to the west and over 3300km from India to the north. The Seychelles have a complex geological history and, uniquely for oceanic islands, they are derived from the Gondwanaland continental landmass rather than a result of volcanic activity (PLUMMER & BELLE 1995). The origin of Seychelles can be traced from the genesis of the South-West Indian Ocean Ridge 200 Mya, when Africa began to separate from Antarctica, forming the south-western Indian Ocean (SADDUL 1995). Between 190-135 Mya (late Jurassic to early Cretaceous), a Madagascan block, with Seychelles and India attached, drifted from Africa creating the Mozambique Channel, and around 120 Mya, it drifted south to Madagascar's present position (COURTILLOT 1999). Primarily due to the formation of the Carlsberg Ridge (DYMENT 1998), between 85-80 Mya, India and the Seychelles separated from Madagascar and drifted north. The Seychelles then separated from India *ca.* 60 Mya (DUNCAN & RICHARDS 1991) and the islands have remained isolated ever since. They have, however, been subject to fluctuating sea level changes, and during Tertiary sea level low stands, their landmass may have been as much as 130,000km² (HAQ *et al.* 1987; ROHLING *et al.* 1998), compared to the present 455km²; thus only the former mountain tops now remain above sea level.

Potentially, therefore, the palaeontology of the Seychelles may be millions of years old. To date, however, bones and teeth referable to *Crocodylus porosus* (GERLACH & CANING 1994; GERLACH 1997) (Table 1) discovered on Mahé represents the only known vertebrate fossil material from the granitic Seychelles, although there is some doubt as to

the provenance of some of this material (see GERLACH & CANNING 1994; Table 1). This scarcity of fossil remains is common to many oceanic islands, primarily due to rapid chemical decomposition (OLSON & JAMES 1982, TENNYSON & MILLENER 1994, WORTHY & HOLDAWAY 1993), particularly relevant to weathered granite sand and the subsequent production of acidic environments, the impact of scavenging, and for topographical reasons. The steep, mountainous nature of the islands coupled with the absence of suitable sedimentary repositories encourages rapid and high energy water run-off (OLSON & JAMES, 1982), thus the majority of vertebrate carcasses are presumably washed out to sea. Furthermore, true soils are very poor for fossil preservation, because they, as opposed to the sediments referred to in this paper, are a result of soil-forming processes in which the break down, transformation, accumulation of minerals and organic matter has occurred, and they have remained stable due to plant roots, compaction etc (see BOGGS 1995). Sediments are generally unstable and uncompacted, with few or no plant root intrusions, and it is within sediments on oceanic/continental islands that almost all fossil material is found.

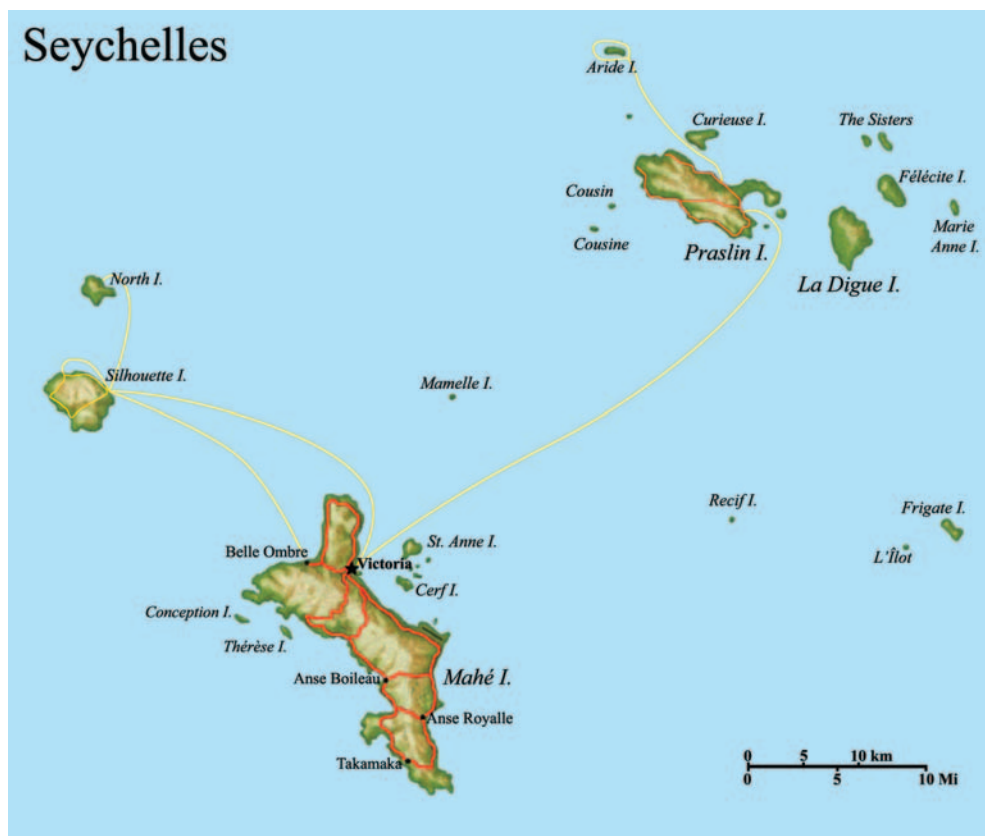


Fig. 1 The granitic Seychelles islands (1:10,000) and the inter-island and overland routes used during the survey.

METHODS

In order to search for fossil bearing localities and vertebrate fossil material, in October–November 2001 I undertook a reconnaissance survey of all of the main granitic islands (Mahé, Silhouette, Praslin, La Digue), as well as the off-shore granitic islets of North Island, St Anne and Aride. This included searching sedimentary basins, e.g. lagoonal deposits, montane and low-lying plateau marsh deposits and boulder field (cave) localities for vertebrate remains by means of small-scale preliminary digging. Localities that were subject to construction activity and agricultural/plantation use were also examined in order to ascertain the potential of searching disturbed sites. The preservation of terrestrial snail shells within a locality was noted as their presence can provide important pointers for finding vertebrate remains. Results are presented here, together with comments on the potential of finding other fossil yielding localities within the archipelago. Surveying was planned using 1:10,000 and 1:5,000 (North Island) ordinance survey maps published for the (Directorate of Overseas Surveys) Seychelles Government. Minimal tools were carried for preliminary research, but these included caving lights, small trowel and fork, collecting bags, compass clinometer, GIS tracker, measuring tapes and photographic equipment. Non-destructive palaeontological methods, e.g. taphonomy, spatial analysis etc, were employed in order to disturb localities as little as possible. Due to the logistics involved, fine sieving apparatus was not taken on this survey, but will be utilised in planned future work. As a result of this preliminary reconnaissance, further fieldwork on the Seychelles is scheduled for summer 2005.

RESULTS

Mahé

Mahé is the largest island of the Seychelles group, being 27km long, 8km at the widest point and having an area totaling 154km². The island is dominated by a tall mountain range with the highest peak, Morne Seychellois, reaching 905m above sea level. Numerous large rivers have eroded the mountains forming steep sided valleys, becoming slow moving and meandering on plateaus and forming deep deposits of silt in sedimentary basins. Substantial delta systems have been created, particularly where the barrier of a coral reef has created a lagoon, e.g. Police Bay, and here water energy is extremely low. Some of the larger and more assessable localities of this type were examined and preliminary test sites excavated. One potential montane site was also examined near the summit of Morne Seychellois.

La Plaine 4°39'02 S, 55°24'04 E.— La Plaine is situated on the central west coast of Mahé and covers an area of approximately 550 x 300m. Mangrove dominates the area, which is divided by numerous watercourses. Sediment banks are high, reaching a depth of 2m+, and comprise coarse sands fining upwards to silt. Invertebrates and crabs are extremely numerous, and much of the visible bioturbation is caused by crab burrows. Test pit digging was undertaken on exposed banks and revealed degraded indeterminate terrestrial snails only.

Grand Anse 4°40'08 S, 55°27'03 E.— An examination was undertaken at the junction of Riviere Dauban and a small delta at Grand Anse (approximately 400 x 300m). Much of the marshy area has been reclaimed and forms part of a coconut plantation, agricultural

farm, timber company and large hotel. The majority of the strata comprised true soils and some spoil heaps were present. The spoil heaps were examined and test pits dug without result.

Trois Freres 4°38'01 S, 55°26'05 E.— The footpath leading to Trois Freres Cross, near the summit of Trois Freres in the Morne Seychellois National Park, passed over a series of montane watercourses and small marshy deposits; despite the dense covering of marsh plants, some exposed sediments were present. Water run-off was notably high and eroded gullies exemplified the high energy involved. Small test digs produced no fossil material, almost certainly due to the steep gradients and rapid run-off of water.

Anse Royale 4°44'05 S, 55°31'00 E.— An examination was made of Anse Royale because it is the only site to have yielded vertebrate fossil remains prior to this survey (see Table 1; GERLACH & CANNING 1994; GERLACH 1997), though precise details as to where the fossil material was collected are unavailable. Only a small area of marsh now exists (approximately 500 x 30m) while the remaining plateau is developed or comprises coconut plantation. Mangrove and marsh plants form dense thickets, thus access was limited. Where sediment had collected, it reached depths of 1m+, but unfortunately, the sediment was contaminated by recent human refuse, even at depth, and unsurprisingly, no fossil material was found.

Anse Poules Bleues 4°44'06 S, 56°27'06 E.— Much of the channel of the Riviere Anse aux Poules Bleues and of the delta entering the lagoon of Anse Poules Bleues is under cultivation, particularly with coconut plantation. Only a very small 10 x 20m area of marsh was discovered and this was overgrown with marsh plants. Where exposed, sediments comprise coarse fining upward sands and silt reaching 0.5m+ in places. Test digging produced no results. This area was named after a probable endemic species of purple swamp-hen *Porphyrio* sp., which was locally called the poule bleu, but had disappeared by the late 18th century without being scientifically described (GERLACH 1997),

Anse Intendance 4°46'09 S, 55°30'00 E.— This marshy mangrove delta is situated on the southwestern edge of Mahé and covers approximately 500 x 200m. The delta is completely surrounded by coconut plantations and made ground. The delta is fed by the Riviere Intendance and evidence derived from undercut banks suggests that water energy is periodically high. Crab and invertebrate burrows are numerous and dense mangrove and marsh plant cover dominate the area, but some exposed banks of sediment are present. The sediments reach 1.5m+ in depth and comprise fining upward coarse sand and silt. Test digging only revealed badly degraded indeterminate terrestrial snail shells.

Police Bay 4°48'00 S, 55°31'03 E.— Police Bay is a marshy delta and lagoon system at the southern most tip of Mahé and covers an approximate area of 400 x 400m. The delta is fed by the Riviere Grand Police and forms a permanent lake at the northern limit. The river system is large and, due to the presence of undercut riverbanks, the energy is assumedly high at certain times. Large numbers of crab burrows are present and there is much evidence of other invertebrate bioturbation, e.g. sediment casts on the sediment surface. Mature forest and mangrove dominate parts of the delta and marsh plant cover is exten-

sive. The sediments are deep at 1.5m+, and comprise coarse to fining upward sand at the rivers edge to silts in the low energy lagoon edges. Test digs revealed some degraded terrestrial snails but no vertebrate material was recovered.

Fossil potential of Mahé.— Moderate to high. Due to the size of the localities on Mahé, further more intensive work is essential, particularly when dealing with deep sediment areas. Mechanical machinery would prove useful to dig through the surface layers, which may have accumulated much more rapidly in recent times as a result of deforestation and subsequent erosion. Other marshy localities not examined during this survey such as Anse Marie-Louise and Anse Takamaka could also usefully be investigated. Further key localities are the inland cave systems on Mahé. Access to these during my visit was prohibited due to the potential disturbance of nesting endangered Seychelles cave swiftlets *Aerodramus elaphrus*, but when examined out of nesting season, these sites may prove productive.

Silhouette

This circular island, the third largest within the Seychelles, is situated 19km off Mahé's northwest coast, and is approximately 5km x 5km and covers 20km². Silhouette rises to 740m above sea level and is probably the least spoilt of all of the Seychelles' granitic islands.

Mare aux Cochon 4°28'03 S, 55°13,09 E.— The Mare aux Cochon is a montane marsh locality covering approximately 1000 x 300m. The area is badly degraded with introduced exotic trees and plantation. True soils occur to at least 2m, as spoil heaps indicate previous agricultural digging activities and the holes are still visible. Marsh sediments exist with typical marsh plant cover. The area is extremely wet and, in combination with a dominance of true soils and abundant tree cover, proved difficult to work. No fossil material was discovered.

Bat cave A, La Passe 4°29'02 N, 55°15'025 E.— Situated at the base of Mont Poules Marrons, this cave locality has been created by undercutting of fallen/eroded granite boulders. Sediments are uncompacted and comprise silt to fine sand, with varying depths ranging from 10-50cm. Sediments are dry and loose deep within the system, but more compacted with minor root intrusion nearer the entrances. Test pits were gently dug using a small fork. Complete and partial shells of the terrestrial snail *Stylodonta unidentata* and small fragments of badly degraded carapace of the giant tortoise *Aldabrachelys/Dipsochelys* sp. were discovered (Table 1) at depths from 5-15cm. The specimens were bleached white (Fig.3) and extremely fragile, indicating that they may have been subject to chemical leaching.

Fossil potential of Silhouette.— Excellent. The discovery of vertebrate material in a cave system, and a number of other potential low-lying plateau areas awaiting investigation, indicate that Silhouette could prove a productive source for future work.

North Island

This small islet is situated approximately 7km off the north coast of Silhouette. It

has three separate peaks, of which the highest, Grand Paloss, reaches 180m. The peaks are situated on the central south, south-eastern and central to northern coasts, and plateaux is centred around the west coast and central south to east coast. The central marsh covers an area of approximately 150 x 100m (Fig. 2). The outer edges of the marsh are covered by dense growth of marsh plants, which become thinner and more stunted toward the centre. Sediments reach a depth of 1-1.5m and comprise fining upward silty sand with a brecciated basal layer of coral fragments and granite.



Fig. 2 North Island central marsh view looking east. Inset: the author with the discovery of the first vertebrate material.

Central marsh 054°E; 142.5°N.— (Fig.2) During my visit, North Island was being developed for the tourist industry and heavy machinery was already in situ. The western edge of the marsh had been partially disturbed by heavy plant, which had removed the top 30cm including the covering vegetation. Two test pits were excavated and the first fossil vertebrate material was discovered (Fig.3). Test pit 1 (6m from the centre of the marsh) produced fossil material at a depth of 30cm, all of which (10 specimens) comprised skeletal elements of giant tortoise *Aldabrachelys/Dipsochelys* sp. (Table 1). None of the material was articulated, but it was generally well preserved and undamaged, indicating that individuals had probably died within close proximity of the marsh and had not been transported via water as disarticulated elements. The disarticulated nature of the material may be a result of mud churning by wallowing tortoises. Test pit 2 (4m from the centre of the marsh) produced more material but at a greater depth (50cm). Of 15 elements collected, 13 are referable to giant tortoise *Aldabrachelys/Dipsochelys* sp., whilst a cranium and partial sternum are referable to the booby *Sula sula* and fregate bird *Fregata minor* re-

spectively (Table 1). The latter two species no longer breed on North Island, although seabirds were reported to do so in the past (Hill *et al.*, 2002).

Fossil potential of North Island.— Excellent. The discovery of the first sub fossil avian material on the Seychelles has very important implications for future work.



Fig. 3 Subfossil material discovered during the survey. From left to right: Cranium of *Sula sula* North Island; partial sternum of *Fregata minor* North Island; carapace fragment of Giant tortoise *Aldabrachelys/Dipsochelys* sp. North Island; carapace fragments of Giant tortoise *Aldabrachelys/Dipsochelys* sp. Bat cave A, Silhouette.

Praslin

Praslin is the second largest island of the granitic Seychelles, being 12km long by 5km wide and covering 37km². Its highest point on the land is Fond Azore at 367m. The island is quite mountainous, with minor areas of lowland plateaux confined to the coastal regions in the south, northeast and northwest. Unfortunately, time was limited during the visit and only the briefest of surveys could be completed.

Vallée du Mai 4°19'09 S, 55°44'00 E.— Within the base of Vallée du Mai, numerous small watercourses have undercut the banks to some depth and an examination was carried out on the exposed surfaces. Badly degraded terrestrial snail shell fragments were recovered but no vertebrate material. True soils dominated the area and sediments comprised only a minor component of the strata.

Anse Marie-Louise 4°21'01S, 55°45'08 E.— This marshy area is situated within a small delta fed by the Riviere Anse Marie-Louise and is approximately 200 x 300m in size. Large trees create a dense canopy in places, with intermittent small shrubs and mangrove. Sediments are deep at up to 1.5m thick. Bio-turbation is evident with small invertebrate casts on the surface and large numbers (~3 per square meter) of crab burrows, some in excess of 20cm in diameter. Test pits revealed the degraded but abundant shell remains of terrestrial snails. No vertebrate material was discovered.

Fossil potential of Praslin.— Moderate. Praslin may prove promising with a more extensive search of low-lying plateaux areas particularly the marshy areas of Anse Madge and west of Grand Anse. Development, however, has already reduced the chances of discov-

ering new localities on some of these sites.

La Digue

La Digue is the fourth largest island at 5.5km long by 3.5km at its widest point, covering an area of approximately 10km². The island is dominated by the Nid D' Eagles, the highest point at 333m, in so much that plateau only occupies a small area of the west coast.

La Mare Soupape 4°21'05 S, 55°49'09 E.— This marshy area is found at the junctions of a number of small rivers draining off the Nid D' Eagles and covers an area of approximately 500 x 500m. It comprises mangrove, mature exotic forest and open marshland. Much of the sediment has deep root penetration and comprises true soils, which made digging difficult. Marsh sediments range from 50cm-1m+ deep but thick marsh plant covers much of the area. A number of test pits were dug up to 1m deep without result.

Fossil potential of La Digue.— Moderate. Due to lack of time, La Digue was not thoroughly examined and further work might prove promising.

St Anne

St. Anne is the largest of 6 small islands lying off the northeast coast of Mahé. It covers 2km² and forms part of the St Anne Marine National Park. Its highest point rises to 250m, with a sandy plateau on the southwest coast.

St Anne has been subject to substantial anthropogenic activity, with much of the plateau disturbed and built over. Large oil storage containers and other buildings are present and the island is presently being developed for the tourist industry. The remaining forests comprise introduced exotics and disused coconut plantations. A marshy area situated on the east side of the islet at the base of the gradient was examined. The sediments were up to 1m deep, comprising fining upward sandy silt deposits. Basal layers were brecciated with coral fragments and small <10cm granite boulders. A large number of well preserved *Stylodonta unidentata* terrestrial snail shells were recovered but no vertebrate material.

Fossil potential of St Anne.— Very poor. The past and progressing destructive activities by man have reduced the potential of finding any fossil material. The introduced exotic plants and coconut plantations have also made access to potentially useful areas impractical.

Aride

This is the most northerly of the granitic Seychelles islets, situated approximately 50km northeast of Mahé and 16km from Praslin. It is 1.5km long by 0.5km wide. The highest peak of Gros La Tete rises to 135m above sea level. Aride is an important world site for breeding seabirds, with probably the largest populations of lesser noddy *Anous stolidus* and white-tailed tropicbird *Phaethon lepturus* in the world, as well as dense populations of many other seabirds (STODDART 1984). The islet also hosts the world's densest populations of terrestrial lizards, most notably large skinks (CHEKE 1984). Marshy areas and tall forest exist on the Plateau, with the forests thinning and become more stunted on

the gradients.

On the plateau, the sediments are deep and compacted in the forested areas with dense and deep root penetration, the majority of which have become true soils. On the gradients, the sediments are thinner and less compacted but mixed heavily with guano and surface leaf litter. The marshland is covered in vegetation, with deep root penetration forming rich humic layers. Large numbers of sea bird corpses were concentrated in catchment areas such as the bases of trees on the slopes, edges of the marsh and the junction of the gradients with the plateau. Dense populations of skinks, in particular *Mabuya sechellensis* and *M. wrightii*, scavenged the corpses and thus many were disarticulated. The examination of sites was limited, but no fossil material was discovered.

Fossil potential of Aride.— Very poor. Too many scavengers are present to expect any large scale burial of specimens and, given the large amount of tree/plant cover, root damage is likely to rapidly destroy buried specimens due to root mineral extraction.

Table 1. List of vertebrate fossil material collected during this and previous palaeontological surveys of the Seychelles

Species	Locality	Element type and number (n)
<i>Crocodylus porosus</i> (Gerlach & Canning 1994; Gerlach 1997)	Anse Royale, Mahé *Presumed Mahé	skull (3)*; maxilliae (2); pre-maxilliae (3); lower jaw (2); jugals (2); teeth (5)
<i>Alabrachelys/Dipsochelys</i> cf. <i>arnoldi</i> . (Gerlach & Canning 1998)	Anse Royale, Mahé *Presumed Mahé	carapace (2)*; vertebra (1); humerus (1)
<i>Alabrachelys/Dipsochelys</i> sp.	Central marsh, North Island	tibia (1); scapula (1); carapace (17); indeterminate fragments (6)
<i>Aldabrachelys/Dipsochelys</i> sp.	Bat Cave A, La Passe, Silhouette	Carapace (7); indeterminate (1)
<i>Sula sula</i>	Central marsh, North Island	Cranium (1)
<i>Fregata minor</i>	Central marsh, North Island	Sternum (1)

CONCLUSION

Two main conclusions are suggested by this short reconnaissance survey of the Seychelles. Firstly, the existence of an array of definite and probable subfossil localities on the Seychelles has been ascertained and potentially more are waiting to be discovered, with the discovery of the first bird fossils (albeit extant species) on North Island exemplifying the possibilities of finding undescribed bird species. In a situation similar to Mauritius and Réunion (HUME *unpubl.*), caves and marsh localities appear to create the right criteria for fossil preservation, but it is apparent that the marsh localities situated some distance from steep gradients have a better chance of retaining fossil material. The recovery of terrestrial snail shells in many localities is encouraging, as their presence suggests that bone material may be preserved as well. The abundance of scavengers such as crabs and lizards, however, is less encouraging as they can seriously influence the preservation

of smaller (<30cm) vertebrates in marsh localities, although cave material should be less affected. Palaeontological material collected during this study and previously (see Table 1), indicate that it is of comparatively recent age, i.e. Holocene (*ca.* <2000 yr.) and categorised subfossil, having undergone little or no diagenetic changes. Although this palaeontological study is not conclusive, it may be expected that the likelihood of finding fossil material of greater age is unlikely.

The second conclusion is one of deep concern. Most of the lowland plateau areas are degraded and are being or have already been lost to tourism, agriculture and community development. Very recently, a potentially important marshy deposit on Praslin has been destroyed by the extension of an airstrip. Such developments, which are also accelerating on other Indian Ocean islands, e.g. the Mascarenes, are removing any opportunity to examine pristine sites. This is extremely regrettable as even the limited material collected on this short reconnaissance has already been analysed for DNA (albeit unsuccessful) for scientific research involving Seychelles giant tortoise taxonomy (e.g. PALKOVACS *et al.* 2002; AUSTIN *et al.* 2003). It would be a great loss to science if the opportunity to discover more material were no longer to exist.

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The establishment of the crested tree lizard, *Calotes versicolor* (DAUDIN, 1802) (Squamata: Agamidae), in Seychelles

PAT MATYOT

C/o SBC, P.O. Box 321, SEYCHELLES
[Pat.Matyot@sbc.sc]

Abstract.— There is evidence that the Asian agamid *Calotes versicolor* (DAUDIN, 1802), the crested tree lizard, is now established on Ste Anne Island in Seychelles, and it is reported to be dispersing away from its original point of introduction. Data collected outside Seychelles on its habitats, reproductive biology and feeding habits show that this species is adaptable, prolific and omnivorous, and it is considered to be an invasive alien species that competes with or feeds on native biota in some parts of the world, such as Singapore and Mauritius. The Ste Anne population needs to be studied and, if possible, eradicated, to prevent this potential ecological threat from reaching other islands in Seychelles, especially those that harbour significant populations of native animals.

Keywords.— *Calotes versicolor*, Seychelles, Ste Anne, invasive alien species.

INTRODUCTION

The crested tree lizard, *Calotes versicolor* (DAUDIN, 1802), is a strong candidate for the status of most widespread non-Gekkonid lizard in the world. GÜNTHER (1864) noted: "This is one of the most common lizards, extending from Afghanistan over the whole continent [sic] of India to China; it is very common in Ceylon [=Sri Lanka]..." Its present distribution stretches from Oman to the west (LOMAN 1997; SEUFER *et al.* 1999) (the following in SAVY (1982) is presumably a reference to Oman: "... more recently the British Museum was sent a specimen from southern Arabia") right across southern and south-east Asia to Indo-China to the east (STUART 1999), the Maldives (HASEN DIDI 1993), Réunion (PERMALNAÏCK 1993), Mauritius (STAUB 1993), (including Rodrigues (BLANCHARD 2000)), Seychelles (MATYOT 2003) and Florida in the United States (ENGE & KRYSKO 2004). With growing evidence that *C. versicolor* is an invasive species with potentially harmful ecological impacts in the areas where it is introduced (DIONG *et al.* 1994; MAUREMOOTOO *et al.* 2003), largely because of its omnivorous feeding habits, it is necessary to gather together the available, albeit limited, information on the status of its presence in Seychelles. At the same time the opportunity is taken to review the existing literature on the ecology of the species with a view to summarizing the available data as a basis for further research on its status as a potential threat. (Among the various common English names used for this species (garden lizard, bloodsucker, etc.) "crested tree lizard" is felt to be the most appropriate in the Seychelles context, to avoid confusion with other species found in gardens, so as not to perpetuate superstitious beliefs, etc.)

METHODS

Video footage of a specimen caught on Mahé in October 2003 filmed by the Seychelles Broadcasting Corporation (SBC) on November 6th 2003 (RACOMBO 2003) was viewed, and interviews were carried out with environment officers and others who have

been involved in sightings of specimens. Photographs of the Mahé specimen filmed by the SBC were sent to two authorities on the genus *Calotes*, HIDETOSHI OTA (Japan) and SCOTT MOODY (USA), who both confirmed it to be *C. versicolor*. (OTA, *pers. comm.* 2003; MOODY, *pers. comm.* 2003). A literature search was undertaken to find all references to *C. versicolor* in Seychelles, as well as references to the ecology of the species worldwide.

Presence in Seychelles

The first observation of *C. versicolor* in Seychelles dates back to the 27th of September 1982 at Barbarons on Mahé island when “a strange lizard ... was found resting in the grass by a young man who handed it over to the Ministry of Agriculture” (Anon. 1982). The specimen measured 38.6 cm long, including the tail, and was therefore probably a fully-grown individual (DIONG *et al.* 1994). It was sent to the Natural History Museum in London, where it was identified as *C. versicolor* (SAVY 1982). In the mid 1980s (“about 1985-1986”) a Seychellois offered to sell two specimens that he said he had found on Mahé to a visiting American herpetologist, RONALD NUSSBAUM, but refused to provide information on where he had captured the lizards when the offer was turned down (NUSSBAUM, *pers. comm.*, 2004). There were no further reports of *C. versicolor* in Seychelles until October 2003, when a specimen was discovered on a *Hibiscus* sp. bush near Anse aux Pins clinic on Mahé (JEANNE MORTIMER, *pers. comm.* 2003; RACOMBO 2003; MATYOT 2003). It was identified as *C. versicolor* by its dorso-nuchal crest, the two widely separated spines on either side of the head above the tympanum, and the absence of any fold or pit in front of the shoulder (OTA, *pers. comm.* 2003). This, the only recent Mahé record, was followed by further sightings, on a regular basis from November 2003 onwards, in the vicinity of the hotel on Ste Anne island, 5 km from Port Victoria on Mahé (LENA DESAUBIN, RODNEY FANCHETTE & MAURICE LOUSTAU-LALANNE, *pers. comm.* 2003; MATYOT 2003), providing evidence that *C. versicolor* is now firmly established on Ste Anne: in November 2003 there were both sexes there, including at least one male seen in breeding coloration (anterior part of the body, including the head, orange-red with a black patch on each side of the throat) and a gravid female that had been crushed by a vehicle, with the eggs that it had been carrying very much in evidence. On January 16th 2004 the Ministry of Environment and Natural Resources announced a bounty of fifty Seychelles rupees for every specimen of *C. versicolor* caught (Anon. 2004). Latest reports speak of crested tree lizards having been observed in parts of Ste Anne away from where the hotel is situated (RODNEY FANCHETTE, *pers. comm.* 2004).

It is not certain how *C. versicolor* was introduced to Seychelles. In view of the long gap of 17-18 years between the 1985-1986 and 2003 sightings, there may have been two separate introductions, an earlier one on Mahé that did not last and a more recent one on Ste Anne that has been successful. One connection between Ste Anne and Anse aux Pins, the locality for the only recent Mahé sighting, is that some of the expatriate hotel personnel working on Ste Anne is known to have accommodation quarters at Anse aux Pins. Unintentional transport by humans is a very strong possibility – it is certainly believed to have played a big role in the spread of *C. versicolor* elsewhere, e.g. the crested tree lizard is said to have been introduced to Réunion island in around 1865 as a stowaway in a shipment of sugarcane (*Saccharum officinarum*, Poaceae) cuttings from Java, Indonesia (PERMALNAÏCK 1993; STAUB 1993). In Florida, USA, however, *C. versicolor* escaped

from a reptile dealer in 1978 (ENGE & KRYSKO 2004).

Review of literature on ecology of *C. versicolor*

Since the 1970s *C. versicolor* has gained importance as a laboratory animal, and researchers in Asia in particular have been using it as a subject for a broad spectrum of biological studies. This has resulted in a considerable output of literature on anatomy (e.g. PARANJAPPE 1974), morphometrics (e.g. TIWARI & SCHIAVINA 1990), endocrinology (e.g. GANESH & RAMAN 1995; SHANBHAG *et al.* 2000), embryology (e.g. MUTHUKKARUPPAN *et al.* 1970; JI *et al.* 2002) and cytology (e.g. OTA *et al.* 2000). However, there is relatively little published material on the ecology of *C. versicolor*. This is surprising in view of its recognized status as an invasive species that is extending its range and, in some colonized areas at least, is impacting negatively on native biodiversity (DIONG *et al.* 1994; MAUREMOOTO *et al.* 2003). The best general account of the species, based on original fieldwork in Singapore, is that of DIONG *et al.* (1994).

On the other hand, several of the laboratory-based studies referred to above have produced findings on the biology of *C. versicolor* that shed light on key aspects of its ecology.

Cytology.— OTA *et al.* (2000) have suggested the presence of cryptic taxonomic diversity in *C. versicolor*, i.e. that “*C. versicolor*” could in fact be a complex of different species, after the karyotype they worked out did not match those recorded by previous studies. It would be interesting to carry out a study of karyotypes from specimens caught in Seychelles and elsewhere in the western Indian Ocean to possibly elucidate the provenance of the Seychellois population.

Habitats.— Being a semi-arboreal, sun-loving lizard that spends a lot of time on tree-trunks and rocks, *C. versicolor* has a predilection for open scrubland, wasteland, gardens, parks and other “man-made habitats” in Asia (DIONG *et al.* 1994; ERDELEN 1984). STUART (1999) reports that it is found on low vegetation in open forest or disturbed areas near human habitation in Laos. In a study of diurnal lizards in the city of Karachi in Pakistan, it was the second most numerous species (KHAN & MAHMOUD 2003). In Réunion, Mauritius and Rodrigues it favours areas of “grassy savannah”, such as that on the west coast of Réunion (BLANCHARD 2000) as well as cemeteries and along roadsides (PERMALNAÏCK *et al.* 1993). In Florida, USA specimens have been collected in an area of grasses and weeds in the vicinity of a canal running along a dirt road (ENGE & KRYSKO 2004). The species appears not to favour dense forest with closed canopies (PERMALNAÏCK *et al.* 1993; DIONG *et al.* 1994; PAWAR 1999). ERDELEN (1984) found it to be most abundant in the driest parts of Sri Lanka. It is reported to occur from sea level to an altitude of 600m (STUART 1999) or even 1,000 metres (DIONG *et al.* 1994). It has a sit-and-wait hunting strategy, usually watching for prey from a vantage point on a tree-trunk, but moving into the shade, including among high grasses, when it gets too hot; adult males stay in the open more often to exercise territoriality, while adult non-breeding females and, especially, juveniles tend to forage on the ground in grassy and shrubby vegetation (DIONG *et al.* 1994; SUNDERASAN & DANIELS 1994). In one study (SUNDERASAN & DANIELS 1994) an adult male was found on the same tree on 15 occasions. *C. versicolor* is reported to be able to swim in both fresh and sea water (PERMALNAÏCK *et al.* 1993). In Florida, USA

38 Table 1 : Aspects of the reproductive biology of *Calotes versicolor*

	VARMA & GURAYA (1975) [India]	DIONG <i>et al.</i> (1994) [Singapore]	RADDER <i>et al.</i> (2002a, 2002b) [India]	RADDER & SHANBHAG (2004) [India]	Ji <i>et al.</i> (2002a, 2002b) [China]	ENGE & KRYSKO (2004) [Florida, USA]
Breeding season	June - September		May - October	May - October	April - June	gravid female captured in August
Clutch size	10-32 (highest number for an Agamid)	22, depending on age & size of female	12-21 (mean 17)	11-29 (mean 19; clutches smaller in late breeding season)	3-14 (mean 9)	19 oviductal eggs in a dissected female
Optimum incubation conditions		moist soil in shade	soil or sand, 27±2°C with exposure to 35°C for 1-3 hours per day		27-30°C	
Incubation period		40-60 days, depending on temperature		70±5 days	60.5 days (27°C) & 51.4 days (30°C)	
Maturation period (from hatching to sexual maturity)		9-12 months				

(ENGE & KRYSKO 2004) as well as in Mauritius (*pers. obs.*) *C. versicolor* roosts on vegetation at night, up to 9m from the ground, usually at the tips of twigs, shoots and inflorescences.

Reproductive biology.— Aspects of the reproductive biology of *C. versicolor*, a multi-clutched seasonal breeder in India (SHANBHAG 2003), are summarized in Table 1. To BHAGYASHRI SHANBHAG and his colleagues at the Department of Zoology of Karnatak University in India we owe a series of studies that have revealed an array of reproductive strategies that help to explain the adaptability of the crested tree lizard (SHANBHAG 2003), among which are the following:

- a) the variation of clutch and egg size depending upon the time of breeding: towards the end of the breeding season clutches are smaller and eggs larger; production of heavier hatchlings at the end of the breeding season may enhance their chance of survival in competition for food, shelter, etc with older offspring from earlier clutches;
- b) the storage of viable sperm by the female for as long as six months, eliminating the need for repeated mating; and
- c) the retention of eggs in the oviduct for six months or even more when conditions are not suitable for oviposition.

Feeding.— Records of prey and other food items of *C. versicolor*, most of them based on observations in India, are summarised in Table 2. It would seem that the crested tree lizard is predominantly insectivorous (according to DIONG *et al.* 1994, “analysis of stomach contents [in Singapore] reveals a diet comprising mainly ants, larval and adult insects, and other small invertebrates”), but it is clearly an opportunistic omnivore that can prey on small vertebrates and feed on plant material as well. One particularly interesting observation (KALITA 2000) is of a crested tree lizard charging and attempting to bite an Oriental magpie robin (*Copsychus saularis*) in a fight over a centipede (*Scolopendra* sp.).

Predators.— *C. versicolor* is in turn preyed upon by a number of carnivorous reptiles, birds and mammals. Published records of predators are summarised in Table 3.

Parasites.— The literature on the parasites of *C. versicolor* is extensive (e.g. DIONG *et al.* 1999; GOLDBERG *et al.* 2003; SATHYANARAYANA & PREMAVATHY 1994; SCHMASCHKE *et al.* 1997) The range of identified ecto- and endoparasites is shown in Table 4, but this is far from an exhaustive list. There may be interactions between parasites: for example, mites have been shown to transmit a species of *Schellackia* (Apicomplexa) to other lizards (BONORRIS & BALL 1955).

Discussion of status as an ecological threat

The continuing extension of the range of *C. versicolor* outside Asia, to the Middle East, the western Indian Ocean and Florida in the United States, is due to a combination of intentional and unintentional transport and introduction by humans. At the same time, the alteration of natural habitats through anthropogenic factors, including deforestation, must have created suitable habitats for the species where there were none before.

Food item	Locality	Source
Earthworms (Oligochaeta)	India	SHARMA 2002
Millipedes (Diplopoda), including <i>Proteros-perhormage</i> sp.	India	AHMED 1984
Centipedes (Chilopoda), including (1) <i>Rhysida</i> sp. & (2) <i>Scolopenda</i> sp.	India	(1) AHMED 1984; (2) KALITA 2000
Dragonflies (Odonata)	India	MITRA 1996
Orthoptera, including grasshopper <i>Chrotogonus</i> sp. (Acridoidea: Pyrgomorphidae)	India	CHANDRA 1983; BHANOTAR & SRIVASTAVA 1985
Termites (Isoptera), including <i>Microtermes obesus</i> Holmgren 1913	India	PARIHAR 1978; MANAKADAN 1993
Wasps (Hymenoptera: Vespoidea)	India	BHATTI 1988
Ants (Hymenoptera: Formicidae)	Singapore	DIONG <i>et al.</i> . 1994
Frogs	India	DANIEL 1983
Small birds	India	DANIEL 1983
Eggs of weaver birds (Aves: Passeridae): Baya weaver (<i>Ploceus philippinus</i>), black-throated weaver (<i>P. benghalensis</i>), streaked weaver (<i>P. manyar</i>)	India	DHINDSA & TOOR 1983

Adult house sparrow (<i>Passer domesticus</i>) (Aves: Passeriformes: Passeridae)	India	PARALKAR 1995
Brook's gecko (<i>Hemidactylus brooki</i>) (Squamata: Gekkonidae)	India	SHARMA 1992b
Young Indian wolf snake (<i>Lycodon aulicus</i>) (Squamata: Colubridae)	India	SHARMA 1999
Hatchlings of flying dragons (<i>Draco volans</i>) (Squamata: Agamidae)	Singapore	DIONG <i>et al.</i> , 1994
Hatchlings/juveniles of <i>C. versicolor</i> (i.e. cannibalism)	(1) India; (2) Singapore	SHARMA 1992a; (2) DIONG 1994
Plant material, including (1) unripe pods with soft seeds of Lima bean (<i>Phaseolus lunatus</i> , Papilionaceae); (2) buds & flowers of <i>Tabernaemontana</i> sp. (Apocynaceae); (3) germinating seeds of <i>Feronia limonia</i> (Rutaceae); (4) dry leaves of mango (<i>Mangifera indica</i>) (Anacardiaceae); (5) flowers of <i>Cassia marginata</i> (Caesalpiniaceae) and <i>Morinda tinctoria</i> (Rubiaceae); and (6) young shoots of cow-pea (<i>Vigna sinensis</i>) (= <i>Vigna unguiculata</i>) (Papilionaceae) chewed but not swallowed, possibly as a source of water	India	BHATTI, BATTI & BATTI 1988; (1) DANIEL & SHULL 1963; (2) SE-KAR 1988; (3) SHARMA 1994; (4) SHARMA 1998; (5) AENGALS 2000 (6) DEVASAHAYAN & DEVASAHAYAN 1989
Faeces of iguana (Squamata: Agamidae)	India	RAJARATHINAM & KALAIARASAN 1999

Table 2: Recorded food items of *C. versicolor*

Table 3: Recorded predators of *C. versicolor*

Predator	Locality	Source
Indian wolf snake (<i>Lycodon aulicum</i>) (Squamata: Colubridae)	Réunion	GUILLERMET 2004
Rat snake (<i>Ptyas mucosas</i>) (Squamata: Colubridae)	India	MUNDKUR 1986
Keeled grass skink (<i>Mabuya carinata</i>) (Squamata: Scincidae)	India	VYAS 1988
Pariah kite (<i>Milvus migrans</i>) (Aves: Accipitridae)	India	PITTIE 1998
Jungle crow (<i>Corvus macrorhynchus</i>) (Aves: Corvidae)	India	KALAIARASAN & RAJARATHINAM 1997
Mynahs (Aves: Sturnidae)	Singapore	DIONG <i>et al.</i> 1994
Jungle babbler <i>Turdoides striatus</i> (Aves: Sylviidae)	India	PARASHARYA & MATHEW 1994

Table 4: A selection of parasites recorded from *C. versicolor*

Parasite	Site of infection in host	Source
Tongue worm <i>Raillietiella gehyrae</i> (Pentastomida: Cephalobaenida)	Lungs	DUTTA & MANNA 1995
Scale mite <i>Pterygosoma neumanni</i> (Acarina: Pterygosomidae)	Beneath imbricating scales of body tegument & tympana	DIONG & HO 2001
Fluke <i>Paradistomum orientalis</i> (Trematoda: Dicrocoelidae)	Gall bladder	MADHAVI <i>et al.</i> 1998
Protozoan (Apicomplexa) <i>Iso-spora lacertae</i> (Coccidia: Eimeriidae)	Intestine? (Oocysts found in faeces)	SAUM <i>et al.</i> 1997
Protozoan (Apicomplexa) <i>Schellackia calotesi</i> (Coccidia: Lankesterellidae)	Intestine? (Sporozoites found in blood & liver)	FINKELMAN & PAPERNA 1998
Flagellate protozoan <i>Proteromonas krishnamurtyi</i> (Slopalinida: Proteromonadidae)	Rectum	SARATCHANDRA & RAMESH BABU 1982

Surprisingly, although it is an adaptable, prolific and omnivorous species, its impact on native biodiversity does not appear to have been scrutinized very closely in the localities where it has become established. However, DIONG *et al.* (1994) have drawn attention to the fact that in Singapore it has “to some extent” displaced the native green crested lizard, *Bronchocela cristatella* (KUHL, 1820); and MAUREMOOTOO *et al.* (2003) include *C. versicolor* in their list of introduced vertebrates thought to have a significant impact on native biodiversity in Mauritius: they state that it competes with native geckos and consumes native invertebrates. VINSON (1968) speculated that *C. versicolor* may have been responsible for the disappearance or rarefaction of phasmids (Insecta: Phasmatodea) in both Mauritius and Réunion. Crested tree lizards have been observed in localities where phasmids have become less common in Réunion: this is the case for *Heterophasma*

multispinosa in the uplands of Saint Joseph and *Monandroptera acanthomera* at Mare Longue (NICOLAS CLIQUENNOIS, *pers. comm.* 2003). In the United States, there is apprehension that “*Calotes versicolor* is yet another exotic species that may compete with or prey upon Florida’s native species” (ENGE & KRYSKO 2004).

In Seychelles, potentially suitable habitat for the crested tree lizard is found in coastal areas and perhaps even on some of the high-altitude “inselbergs” of the inner, granitic, islands as well as extensively in the outer, coralline, islands. While Ste Anne, its present focal point, is itself not a high-value island in terms of terrestrial fauna and flora, if *C. versicolor* were to disperse to other islands this could represent a serious new threat to native biodiversity, with prey records from India and elsewhere (Table 2) showing the wide range of groups of organisms that could be threatened. The smaller, rat-free islands with extensive seabird colonies and populations of endemic terrestrial birds, invertebrates, amphibians (Caeciliidae on Frégate) and reptiles (GERLACH 1997) would seem particularly vulnerable. It is not clear to what extent the parasites harboured by *C. versicolor* are host-specific, i.e. whether some of them, at least, can infect native lizards like skinks (*Mabuya* spp.) and geckos (e.g. *Phelsuma* spp.) as well. It is likely that in Seychelles *C. versicolor* would be preyed upon, especially in the juvenile stage, by the endemic snakes *Boaedon geometricus* and *Lycognathopis seychellensis* and the endemic Seychelles kestrel *Falco araea* as well as domestic and feral cats (*Felis domesticus*); but it is doubtful that they would suppress the population of such a prolific and fast-maturing breeder.

Research is urgently required to elucidate the status and ecology of the established population of *C. versicolor* on Ste Anne island even if eradication efforts announced by the Ministry of Environment and Natural Resources are ongoing (Anon. 2004). Captured specimens could be sexed, measured, weighed and dissected for stomach contents and, possibly, parasites. Managing the spread of invasive alien species involves (1) prevention, preferably, to keep potential invaders from entering a new ecosystem; (2) early detection, if prevention is not successful, to locate the alien before it has the chance to become established and spread; (3) eradication, mostly possible when the alien is detected early; and (4) control as a long-term process to limit the population size and distribution of the alien if eradication is not possible (REASER 2003). In the Seychelles context, to manage the spread of the crested tree lizard would involve all of these going on at the same time on different islands within the archipelago.

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The Seychelles sheath-tailed bat *Coleura seychellensis*: monitoring methodologies and recom- mended priority actions

GÉRARD ROCAMORA* & FLAVIEN JOUBERT

Ministry of Environment, Botanical Gardens
PO Box 445, Victoria, Seychelles.

(*):BirdLife International consultant
Present address: Island Conservation Society
PO Box 775, Victoria, Seychelles
[ics@seychelles.sc]

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Abstract.— The Seychelles sheath-tailed bat *Coleura seychellensis* is Critically Endangered with fewer than 30 individuals censused in 1996/1997. The surviving population is estimated to be as low as 50 to 100 individuals. Records from the last century and popular reports indicate that a strong decline in numbers and probably range has occurred. The species is present on Silhouette, Mahé, Praslin, and possibly already extinct on La Digue. Recommended monitoring comprises annual census of individuals along established transects using bat detectors, regular visits to all known caves and census of individuals, searches for roosting caves nearby repeated contacts with the species and assessment of the evolution of its distribution every 3 or 4 years. The main conservation actions required are legal protection for all known roosting caves and their immediate surroundings, control of introduced predators (barn owls and cats) in these areas, habitat protection within known feeding area and public sensitisation to help protecting the species and obtain information on feeding areas or roosting caves. Research into the biology and autecology of the Seychelles sheath-tailed bat is required, including basic information on feeding ecology and diet, habitat preference, movements, roosting habits and breeding ecology.

Historical and ecological background

The Seychelles Sheath-tailed bat *Coleura seychellensis* PETERS, 1868, called ‘Sousouri banann’ (chauve-souris banane) in Creole, is a critically endangered species listed under the IUCN Red Data Book of the Globally Threatened Species of bats of the world. Its population is currently estimated no more than 50 to 100 individuals in the four major granitic islands of Seychelles: Mahé, Praslin, Silhouette, and La Digue, where it could be already extinct. Two subspecies can be distinguished : *C. s. seychellensis*, recorded from Mahé and Praslin, and *C. s. silhouettae* from Silhouette and La Digue (HILL, 1971).

Monitoring and searches have been conducted in 1995 by JOUBERT (1995), 1996 and 1997 by a Ministry of Environment team (SELBY RÉMIE, ROLAND NOLIN, PERLEY CONSTANCE, FLAVIEN JOUBERT & GÉRARD ROCAMORA; see ROCAMORA, 1997; volume

2) with some participation from Glasgow University Expedition in 1996 (MELLAMBY *et al.* 1997) to develop a first general overview of the population size and distribution of *C. seychellensis*. Only 5 to 7 bats were found on Mahé, 2 on Praslin and none on La Digue during extensive transects covering most of the road network of these 3 islands in 1997. On Silhouette, only 20 individuals were counted in a roosting cave in 1996 (JOUBERT 1996) and 17 in 1997 (ROCAMORA *et al.* 1996). A monitoring database has also been set up (ROCAMORA 1997; Vol. 2).

The roosting cave of Silhouette is the only known at present. It is situated at low altitude in Silhouette island (JOUBERT 1996; ROCAMORA *et al.* 1996). A roosting cave was known or suspected in the past on Mahé (JOUBERT, *op. cit.*), but the cave is currently unoccupied. One cave was also known on Praslin, and one on La Digue (NICOLL & SUTTIE 1982), but have not been located and visited since then. This species has apparently gone through a dramatic decline in numbers and probably range as well. WRIGHT (1868) noted that the species was very common near Port Victoria, and historical popular reports show evidence that this bat was much more abundant in the past (elderly residents remember large numbers emerging at dusk on Mahé, or caves with large numbers; NICOLL & SUTTIE, *op. cit.* ; JOUBERT, *op. cit.*).

In total, the minimum population known to exist is less than 30 individuals, very sparsely distributed, and the total population can be estimated between 50 to 100 individuals. It is extremely urgent to undertake the necessary research and conservation work to save this species from extinction.

Monitoring

The basic monitoring of the Sheath-tailed bat should include:

- * annual census of individuals detected along established transects using bat detector
- * searches for roosting caves nearby repeated contacts with the species
- * regular visits to all known caves and census of individuals
- * an assessment of the evolution of its distribution every 3 or 4 years

Annual transects

Since we do not know precisely the preferred habitats of *Coleura seychellensis*, certain assumptions regarding its spatial and temporal occurrence may need to be remodelled depending on the outcome of future research and monitoring to be conducted on that species.

Considering the outcome of earlier trials, the species seems to have a preference for coastal and low altitude habitats, and to be more likely to be contacted at dawn or at crepuscular hours. Therefore, observations along transects should be carried out at dawn (04:30 - 06:00) and dusk (18:30 - 20:30).

What is being monitored along the transects is essentially the vocalisation of the bat which is very distinctive and easily detected with a bat detector. In such a nocturnal species, it is the best indicator of its presence. Sometimes, however, bats can also be seen and counted.

We do not know whether there is a particular period of the year during which feeding bats would be more detectable. Two types of transects, Walking transects and Car transects, should be carried out.

Walking transects.— Permanent walking transects have been established on Mahé, Praslin, La Digue and Silhouette. An open set of criteria have been used for establishing walking transects but the most important ones were, former presence of *C. seychellensis*, accessibility and distance. On Mahé, 3 walking transects could easily be defined as there exists already known specific areas when *C. seychellensis* has been recorded. On Praslin, only 2 short walking transects were tried in two areas where bats had been first contacted by car transects. In La Digue, a combination of walking and bicycle was used along the main road/path transects. On Silhouette, transects cover the two plateau areas of La Passe and Grand Barbe.

- | | |
|-------------|--|
| Mahé: | 1. Grande Anse-Béolière-Mahé Beach
2. Port Launay-CapTernay
3. Bel Ombre -Anse major |
| Praslin: | 1. Anse Madge
2. Baie Pasquière. |
| La Digue: | 1. L'Union entrance-Anse source d'argent
2. Grande Anse - Anse Coco |
| Silhouette: | 1. La Passe plateau
2. Grande Barbe plateau |

Walking transects allow more detailed searches. More of them could be defined in future years depending on new areas of presence of the species that could be found.

Car transects.— Searches from a moving vehicle were found adequate to prospect for the presence/absence of the bats along road transects. These road transects cover most of the main road network for Mahé and Praslin (done by car) and La Digue (done by bicycle). It allows greater coverage of larger areas that would otherwise have taken longer by other methods. Once bats were detected from the vehicle, more precise searching was done by foot. Contrary to what may be expected, wind and engine noise did not appear to have any major effect on the performance of the detector nor detection of bat calls.

Equipment.— Monitoring can be done with sound detectors like Batbox III and Mini III detectors, both tunable. They are similar in sensitivity and call resolution but there is comparatively more noise from the Mini III detector. Higher performance models like U30 can also be used. Detectors were set to just below 40KHz, as there exists a relatively stable and intense call component at that frequency. The disadvantage of such a high frequency is that it attenuates faster and thus imposes limits on the detectable distance, which is around 50 meters (note that the calls of *C. seychellensis* reaches as low as 25Khz).

Observation and transect forms.— For each contact with the species done along a transect, a number of parameters should be recorded on an observation form. This includes the location (with precise map), time and altitude, the meteorological conditions especially regarding the presence of wind or rain, a rough description of the habitat (vegetation layers, presence of water, particular features, etc.), the activity of the bats detected (flight, vocalisation, interactions) and eventually some information on their feeding. Feeding rates can be determined by counting the incidence of feeding buzzes with the bat

detector and information on the type of prey they are hunting can sometimes be obtained by direct observation.

The problem with this type of transect method is when do we consider that two consequent contacts with the species along the same transect represents different individuals. In order to standardise our method, we have decided that encounters over short distances (less than 100m) should not be considered as distinct individuals, the chances to count two times the same individual being too important.

At the end of the transect, results obtained during the transect are summarised on a transect form (attached), for later input into the database.

Remarks.— The number of individuals recorded using bat detector along established permanent transects could be used as an indicator of the population status. However, due to the present very low number of individuals encountered along the transects, this is unlikely to be used as a statistically significant index when comparing results obtained for different years.

A minimum of one survey per year shall be made on all four islands where this bat is known to exist. However, depending on resources and other activities' schedules, the coverage of the survey could be increased.

It is interesting to note that only a certain percentage of the resident population of bats can be detected along the transects. For example out of the 20 individuals present in La Passe roosts on Silhouette, only about half of them were recorded during walking transect on the La Passe plateau (JOUBERT 1996).

Searches for caves with roosts

Searches for caves holding possible roosts must be organised systematically in the vicinity of areas where bats have been contacted repeatedly during transects. This is particularly valid for early morning contacts of bats at dawn, less likely to be far from their roost.

Caves can be located during the day, but because these endangered bats are likely to be extremely sensitive to disturbance, caves should be entered only during that time of the day when the bats are likely to be least active and possibly even torpid. This may be in the early morning when the temperature is likely to be the lowest (RACEY, *pers. comm.*).

Once located, roosts should be legally and adequately protected against any kind of human activity or interference, and their location should not be publicly advertised.

Visits to caves and roosts counts

Being a critically endangered species extremely sensitive to disturbance, monitoring activities in caves with roosts should be reduced to the strict minimum and always been undertaken with extreme silence and precautions.

It is likely that *C. seychellensis* is as sensitive to disturbance as *Coleura afra* studied by McWilliam in Kenya, two colonies of the latter having declined as a result of adjacent tourist developments and a general increase in human activity (Racey, *pers. comm.*). In general, larger colonies of bats appear to be more stable and the smaller the colony the more sensitive to disturbance it should be.

Whenever possible, the roosts should be counted from the entrance with tripod

mounted binoculars (MCWILLIAM, *in lit.*). Visits to the caves should not be too frequent, and limited to annual (or maximum quarterly) visits for basic routine monitoring. However visits in the vicinity of the area where the cave is situated can be done more frequently to prevent any threat or development to take place, especially when roosts are located near settlements, or when human activities take place nearby.

Any information related to the reproductive cycle (observation of mating, presence of young) should be noted on an opportunistic basis, but no specific monitoring of the breeding success is possible within the frame of such basic monitoring. Faeces can also be collected by night from the roosts, at a time when the bats are foraging and absent from the roost. Faecal analysis should be given a high priority in any future research programme willing to determine the species diet (by identifying insects from fragments of exoskeleton).

Distribution monitoring

Every 3 to 4 years, all existing data should be put together to produce a distribution map of the species (using a 1×1km square-grid for example) covering each of the four granitic islands, in order to monitor the evolution of the distribution of the species (see distribution map for 1996-1997 surveys in ROCAMORA 1997, volume 2).

Results from all road and walking transects and cave visits should be entered into the database created at the Conservation section of the Ministry of Environment for this purpose and where all observations from 1996-1997 have been stored (SUSURDTB.XLS; in ROCAMORA 1997; vol. 2)

Recommendations for conservation and research

Since the world population of that critically endangered bat might well be comprised between 50 and 100 individuals only, it is extremely urgent to undertake the necessary research and conservation work to save it from possible extinction.

Location and protection of roosts and feeding areas

A research and conservation programme should in the first instance be aimed at locating and protecting roosts, understand why the species is in such a critical situation and what should be done for its recovery. A project proposal was prepared with this purpose and forwarded to funding agencies (see conservation projects, ROCAMORA 1997 volume 3, for more details). All known roosting caves should receive legal protection status protecting them against any kind of development or human activities in the vicinity of the caves. The same applies to feeding areas that need to be located, and then protected. Introduced predators such as cats and barn owls should be trapped and eradicated from roosting caves and their immediate surroundings.

Biology and autecology

The biology and autecology of the sheath-tailed bat remain largely unknown and need to be studied. Consistent efforts are needed to obtain basic information on feeding ecology and diet, habitat preference, movements, activity rhythms and behaviour, roosting habits and breeding ecology, interaction with other species, including parasites. Present knowledge on its status also needs to be improved. It is extremely important not to undertake any activities that could create disturbance at roosts and put in jeopardy the survival

of the species. This should help to identify factors limiting the size of the sheath-tailed bat population, present and potential threats, and to propose conservation measures.

Public sensitisation

Exposure of *C. seychellensis* as a highly endangered species should be sustained. Public sensitisation is also very important for an effective protection of this extremely fragile population, and also to obtain information about new sites (feeding areas or roosting caves) occupied by the species.

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A preliminary investigation into the general ecology, status and habitat of the Seychelles sheath-tailed bat *Coleura seychellensis* (Emballonuridae)

FLAVEIN JOUBERT

Ministry of Environment & Natural Resources,
P.O. Box 445, Victoria, Mahé, SEYCHELLES
[f.joubert@env.gov.sc]

Abstract.— An evaluation of the occurrence of the Seychelles sheath-tailed bat (*Coleura seychellensis*) on the islands of Mahé and Silhouette (Seychelles) was attempted. Abandoned caves were documented. The presence of *C. seychellensis* was confirmed for Mahé and a previously unknown population was located and studied on Silhouette. Techniques for field study, habitat and diet analysis were successfully applied to *C. seychellensis*. Most of the results were limited but foraging, habitat and population are discussed and some conclusions are drawn.

Keywords.— foraging, biomass, echolocation, Silhouette

INTRODUCTION

Bats (Chiroptera) are presently one of the world's most endangered mammal groups. Insufficient knowledge of many species has led to human induced changes having negative effects on populations. Island populations such as Livingstone's flying fox (*Pteropus livingstoni*) in the Comoros islands (HUTSON 1994) are particularly vulnerable to encroachment and disturbance by humans.

Although flight and a nocturnal nature allows bats to exploit little used resources such as flying insects, it has also resulted in a greater need for adaptations and more acute performance. Flight itself is physiologically a very demanding propulsion method, imposing limits on body parameters such as weight and imposing demands on food intake. Bats do not only have to contend with flight and its limits; maximising foraging coverage does not necessarily entail greater gain per unit effort due to other factors, such as the aerial performance and detection abilities. Thus the strategies involve compromises between the different demands (BARCLAY & BRIDGHAM 1991). Detection of prey and obstacles is achieved by the use of high frequency ultrasonic calls to convey information on the position, velocity, texture and size of prey.

The old world genus *Coleura* (Emballonuridae) appears to be limited in species but is fairly widespread within its range in Arabia and sub-Saharan, Africa. Available literature cites the presence of one species (*C. afra*) on mainland Africa and another, *C. seychellensis* PETERS, 1868, restricted to the granitic islands of Seychelles (HILL & SMITH 1984). Apart from the plant feeding pteropodid fruit bats this is the only mammal species endemic to these islands (RACEY & NICOLL 1984). In NICOLL & SUTTIE (1982; after

HILL 1971) it is treated as having two subspecies, *C. s. seychellensis* and *C. s. silhouettae*, the former inhabiting Mahé and Praslin and the latter Silhouette and La Digue. From what can be gathered *C. seychellensis* appears to have been abundant up to the late 70's. Older people recall seeing large numbers emerging *en masse* at dusk to feed around Victoria and Mammelles (Mahé), and visiting caves containing thousands of bats on Silhouette (Silhouette residents *pers. comm.*). This claim is further substantiated by abandoned caves on most of the islands (see results and also NICOLL & SUTTIE 1982). Agreement with TUTTLE (1979) that guano deposits are good indicators of numbers would lead to the conclusion that the magnitude of decline may have been as high as 90%. Recent sightings indicate that *C. seychellensis* is now extremely rare, but also that small fragmented populations still remain on all four islands,

Ever since the first colonisers arrived in the late 18th century the Seychelles islands endured human interference and alterations to habitats. Present day animal and plant communities give only a general idea of the original ecology; some documentation is available on the original biota but much testifies to a legacy of plunder and mismanagement. Of the human induced ecological changes which may have had effects on the population of *C. seychellensis* the most visible is that of vegetation change.

SCOTT (1933), in a detailed report on the Seychellois insects commented on the level of association between insects and the endemic and indigenous plants. Considering the proliferation of secondary vegetation, an immediate conclusion would be that insect species may have changed accordingly. In a short term study BROWN (1984) argues that vegetation successional stages have associated with them insects with distinct life history traits, an argument which follows the r to K changes in size, mobility, and niche breadth. GASTON & LAWTON's (1988) statistical analysis of insect datasets adds weight to the idea of small size being a characteristic feature of insects of early successional stages, with size being considered as a factor determining distribution, variability and abundance. However a strict negative correlation is ruled out, which means that some of the theoretical assumptions may not hold true. Similarly WOLDA (1987) in evaluating disturbed habitats in Panama concluded that the effects on insect populations were not as extreme as predicted.

BARCLAY & BRIDGHAM (1991) give an explanation of the relationship between detection ability, body size and prey size in aerial insectivorous bats. The negative relationship between body size and vocalisation frequency indicates that dietary niche breadth is restricted for large but not for small species. In the light of the ecological changes it is apparent that changes in prey availability may have affected *C. seychellensis*. The present study considered predator-prey relationships in the context of selection and limits to available prey to help resolve the question of selection and availability. This work was carried out as a final year project for the BSc in Environmental Studies at Manchester Metropolitan University in 1996.

METHODS

Numerous established techniques were used for field study and analysis of use of habitat by *C. seychellensis*. Most work was carried out on Silhouette island as bats from the roosts (A&B) forage over the area, it contains a variety of habitats and work could be carried at any time (early morning & evening) due to relatively easy access. Sticky traps were used for insect sampling on Silhouette in August and September 1995 at the La

Passe site. Vegetation analysis and cartography were also carried out at the Silhouette site. Echolocation surveys were carried out on Mahé and Silhouette between July and September 1995 following from trial surveys on Mahé in August 1994. The echolocation survey covered the whole of north and north-west Mahe (to Belombre). On Silhouette it was carried out on the east coast from La Passe to Anse Lascars. Faecal matter was analysed at the Seychelles Polytechnic, Anse Royale, Mahé.

Likely roosting caves on Mahe, Silhouette and La Digue were visited during 1994 and 1995. Cave characteristics and evidence of occupation by bats, such as guano, were recorded.

Echolocation surveys

The use of ultrasonic calls of bats for the determination of numbers and activity is well documented (FENTON *et al.* 1987; FULLARD 1989). Calls of species are distinct and temporal coincidence amongst individuals is rare, allowing tracking even in circumstances whereby many individuals are present. Apart from allowing the detection and estimation of numbers of foraging bats without visual contact, it can also be used to determine the frequency of prey capture (FENTON 1985) and other social interactions. It is presently one of the most recognised techniques in bat research (THOMAS & LAVAL 1988) as it is non intrusive and relatively easy to use. In this particular case there was no other echolocating bat species and the frequency of calls of *C. seychellensis* was known in advance from trials carried out in 1994. Likely feeding places were patrolled using Batbox II and Limbrick bat detectors at different times of the evening to ascertain the distribution of feeding bats. In most cases the Batbox detector was tuned to 40kHz but this was varied in the proximity of feeding bats to work out call patterns. Areas for error are minimal when using this approach but it was found that the song of certain insects and other noises could sometimes cause interference, but it was relatively easy to discriminate between these background noises and bat calls. The performance of the Limbrick detector was poor when it came to resolving call patterns and this coupled with a shorter range to limit its use.

Prey sampling

Sticky traps were the most appropriate method of sampling because of the ease of construction and use. It is a non-selective method, as opposed to attractors such as light traps, guarantees almost 100% retention of trapped insects and also does not require power or expensive material. Although the efficiency of this method is dependent on wind velocity (KUNZ 1988) its efficiency is constant between 2-10mph, with highest efficiency at low wind speeds (TAYLOR 1962). Cylindrical sticky traps present an omnidirectional sticky surface which entangles flying insects upon contact. Under calm conditions it will therefore be independent of air movement as it collects insects flying from whichever direction, but the situation changes with strong wind as certain small insects may be carried along in the airstream. During the study period wind conditions were calm.

Five sticky traps were used for sampling. These were constructed out of 50cm lengths of 4 inch PVC pipes over which was stuck white cotton fabric, giving a total area of 1,728cm². Trap surfaces were coated with Oecotak non setting glue. All traps were wrapped in clingfilm before and after deployment. Sampling was carried out over three nights; on the first night sampling was random on the coast and hill and on the two re-

maining nights sampling was done along a transect from the roost down to the coast. Traps were set at 6pm and retrieved at 6am in all cases, those times corresponding to sunset and sunrise. On the hill traps were set above the canopy whilst on the coast they were set at half canopy height. This strategy was adopted firstly because of the safety aspects and logistics of setting and retrieval of traps. Traps could be set on a pole above the relatively low canopy of the hill vegetation, but the vegetation type and high canopy (>20m) of the coast prevented such an operation. In addition it was found that bats fed within the vegetation and at lower than half the canopy height on the coast, whilst on the hill low level foraging was prevented by the closed canopy.

Trap contents were identified to order level using BOROR & DELONG (1964) as a guide. Measurements of length and width were taken in millimetres, but for small individuals the dimensions were estimated to the nearest 1/3 or 1/2 millimetre.

Analysis of faecal material

Faecal analysis is one of a few methods available for working out prey utilisation in bats, as the actual taking of prey is virtually impossible to monitor in aerial insectivorous species. It is also non destructive method (WHITTAKER 1988) used successfully in past studies (JONES 1990), and is especially recommended for insectivorous species as the exoskeleton of insects present readily identifiable fragments (WHITTAKER 1988). The method can be used in conjunction with prey availability data to test for prey selection and habitat use.

25 faecal pellets were collected from roost A (La Passe) during the insect sampling period. Collection was achieved by spreading three plastic sheets (50x50cm) under the points with greater guano accumulation for eight days. Pellets were frozen in individual containers (small plastic petri dishes). Before analysis each sample was moistened with a detergent solution and left to loosen for 24 hours. This is different from the method proposed by MCANEY *et al* (1991) or that used by JONES (1990) which makes use alcohol for wetting, but it was found to be as effective in loosening the samples. Samples were prised apart using fine dissecting needles and analysed under a binocular microscope at x40 and x100 magnification (Carl Zeiss Technical microscope, courtesy of Seychelles Polytechnic, Humanities and Sciences). All identifiable parts were drawn under dark ground illumination and later classed according to order using BOROR & DELONG (1964), WHITTAKER (1988), RICHARDS & DAVIES (1977), MCANEY *et al* (1991) and CHAPMAN (1982).

Vegetation analysis

Vegetation in the sampling area was recorded by using a transect and quadrate. The dimensions of the transect was calculated so that it could accommodate a quadrat of minimum size. Minimum quadrat size was calculated from a species area curve, as outline by GOLDSMITH & HARRISON (1976). According to SPELLERBERG (1991) the minimum area is the point where the slope of the curve approaches 10%. In this case however the inception point was found to be inadequate (just over 20m²), and the minimum area was taken as a higher value (80m²) corresponding to a second change in the species area curve. Transect width was thus taken as 10m so that it could accommodate quadrates of 10x8m. Within the transect 10 such quadrates, equidistant from each other were used for vegetation analysis. Plant species were identified from ROBERTSON (1989), and canopy dimensions were recorded for all species present (excluding grasses, herbs and climbers).

RESULTS

Table 1 lists roosting caves encountered during the 1994 and 1995 surveys. Note that most area at low altitude. Other caves with possible signs of occupation were found at Cap Matoopa and Cap Ternay (Mahé). These have not been listed as material collected was not positively identified as bat guano. An attempt was made in 1995 to try and locate the cave on La Digue mentioned by NICOLL & SUTTIE (1982); a wide area was covered but no cave was found.

General observations

Foraging bats were found at two sites on Mahé on 02 August 1994; two individuals were found separately at Anse Major (west of Danzil) and two more together at La Gogue (reservoir area). Another foraging bat was recorded at Machabée on 21 July 1995. Observations on feeding bats agree to some extent with the conclusions drawn from wing morphology by NICOLL & SUTTIE (1982); namely that *C. seychellensis* is a high and fast flying bat. It showed however that to assume complete restriction on flight performance by morphology may be somewhat erroneous and ALDRIDGE's (1986) conclusions give cause for deviating from the basic assumption derived from PENNYCUICK's equation for gliding flight (PENNYCUICK 1975). High and fast flight was observed only rarely and these involved only a few individuals and were under windy conditions (20m altitude with swoops to 5m, observed Mahé 1994 and Silhouette 1995). In most cases bats fed at low speeds in relatively cluttered surroundings (e.g. within the coastal vegetation, Silhouette).

Table 1. Roosting caves on Mahe and Silhouette

Location		Description	Visited	Notes
Mahé	La Reduit, Takamaka	10m altitude. Steep rocky coastal location, dry, 2 <i>Pandanus</i> species, 4m ceiling, 2m guano deposit	July & Sep 1995 No bats	Indication of a small population some time ago
	Silhouette	Grand Barbe	July 1995. No bats	Indication of large population or long term occupation. Residents claim that bats were present up until recently.
		Pointe Coco	July 1995 No bats	Some time may have elapsed since last occupation
	La Passe	A 30m altitude in boulder field Mixed vegetation, palms and exotics, ceiling 1.5-3m, slight angle, large guano deposit	July & August 1995 14 bats	These bats were the subject of this study. Counts may have an error of ± 3 . All appeared mature, population structure was not investigated
		B ceiling >3m, angle slight to steep, 3m guano deposit	11 bats	

A best approximation of foraging vocalisation in *C. seychellensis* would be of the long narrowband constant frequency (CF) type with a shallow PM terminal phase, in agreement with NEUWELER and FENTON's (1988) classification of its closest relative *C. afra*. Two major harmonic bands were identified at 40kHz and 25-30kHz, with the terminal FM sweep reaching high in the audible range. Roosting bats were found to be non-

vocal, unless disturbed, when high pitched audible calls were made. When flying within the roost bats produced audible orientation calls.

Emergence patterns were not monitored (cave characteristics and personnel being limiting factors), but the success of encounters at different times in the evening suggest that *C. seychellensis* may exhibit a bi-modal pattern of emergence, concentrated around late evening and at dawn. Dawn observations on Silhouette proved more fruitful often with over ten individuals feeding gregariously and remaining in the same area (marsh area) until it got light. Evening sightings were often one or a few individuals, most of which were transitory. The observed pattern however may have been a result of circumstances during the study period as activity could be influenced by such diverse factors as lunar cycle (ERKERT 1982) and spatial and temporal distribution of prey (BRADBURY & VENRENCAMP 1976).

Some disparity in size was observed, especially when individuals flew together within the roost. It is known that *C. seychellensis* is sexually dimorphic (NICOLL & SUTTIE 1982) but no attempt was made to work out population structure using that approach as growth stages could easily invalidate the data.

Most bats transferred from roost A to roost B when disturbed (B was left undisturbed throughout the whole period), although some individuals tended to roost in the open. This could be linked to some form of territorial behaviour observed both at the roost and in foraging bats whereby chasing would be accompanied by a continuous stream of clicks (which were audible at the roost).

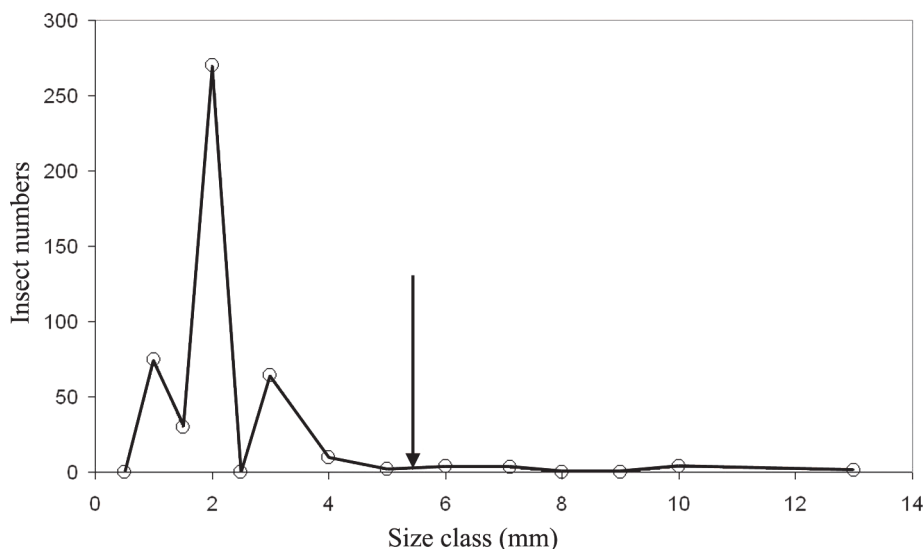


Fig. 1 Insect size distribution

Insect prey data

Prey size distribution.— Fig. 1 shows the size distribution of insect sizes for all fifteen

traps. The distribution is highly skewed towards lower sizes. Tests for skewness and kurtosis (EBDON 1995) give very high values: skewness = 2.1, kurtosis = 6.5. The values show that the insects sizes present are not normally distributed, and further statistical analysis was not carried out.

Minimum size limit.— Minimum size limit is calculated on the assumption that the minimum size detectable is a function of the shortest wavelength attainable, in other words highest frequency. 50kHz was taken as the upper vocalisation frequency of *C. seychellensis* (see below), this corresponds to a wavelength of 6.88mm (effectively equivalent to the smallest detectable target). MOHL (1988) defines acoustically small targets (in bats) as those which satisfies the equation (where a = target diameter, λ = wavelength) :

$$2 \times \pi \times a / \lambda = 5$$

Applying this equation to a frequency of 50kHz gives the lower value of 5.47mm as the minimum detectable size.

Biomass of size classes.— Fig. 2 shows mean biomass for the different size classes, for ease of calculation each insect is assumed to be uniformly cylindrical, and volume calculated using the equation for a cylinder. BRADBURY & VEHRE CAMP (1976) used length as a measure of biomass, but this was not used as it gives an ideal pattern, independent of the width of individuals. Total biomass itself does not show such a trend of increasing values; high variability together with the skewness in number tends to dampen such a trend.

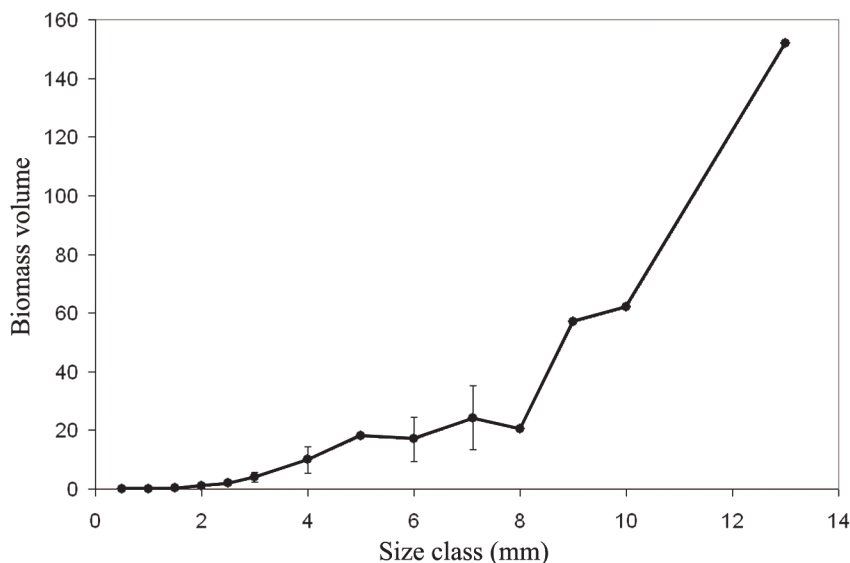


Fig. 2 Biomass distribution

Size and biomass of taxa.— Fig. 3 shows the distribution of sizes and biomass for the insect taxa present (error bars equals one standard deviation). Low abundance for certain orders such as Hemiptera prevented a more accurate calculation of the mean size.

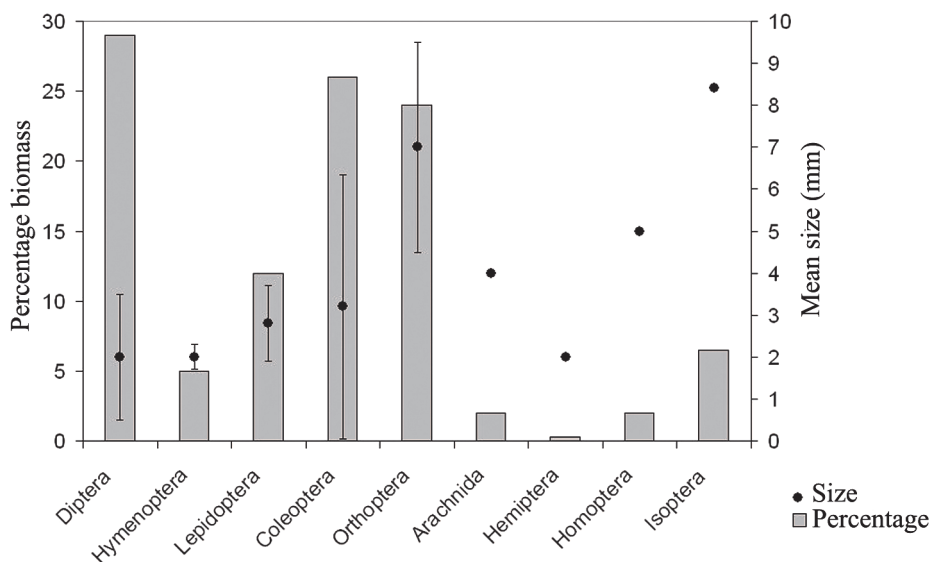


Fig. 3 Biomass and size of invertebrates. Error bars represent one standard deviation

Prey and prey consumption

Insect fragments and identification.— Insect numbers in each sample were estimated by calculating the minimum number of individuals for the fragments present (WHITTAKER 1988) (Fig. 4, Table 2). For a few samples difficulties with the type and size of insect fragments meant that identification was not complete, but that applies to.

Table 2. Summary of prey available and eaten

Order	Total		Over 5mm		Percentage eaten
	% prey	% biomass	% prey	% biomass	
Diptera	40	28.8	18.8	24.6	30.5
Hymenoptera	48	4.8	6.3	2.6	25
Lepidoptera	6.3	10.3	6.3	1.9	19.5
Coleoptera	2.5	24	12.5	25.4	22
Orthoptera	1.8	22	37.5	32.5	0
Arachnida	0.5	1.2	0	0	0
Hemiptera	0.2	0.1	0	0	3
Homoptera	0.2	1.3	6.3	1.9	0
Isoptera	0.5	7.5	12.5	11.1	0

Analysis of preference.— Fig. 5 give the results for analysis of preference using Cock's (1978) method 4 for all combinations of prey present. The same procedure was also repeated for insect numbers above the 5.47mm size limit (taken as all above 5mm) derived above. The clumping of data and apparent preference of most species over Diptera and Hymenoptera is replaced by a more complex relationship between the common taxa and high selectivity against Orthoptera when only large insects are considered.

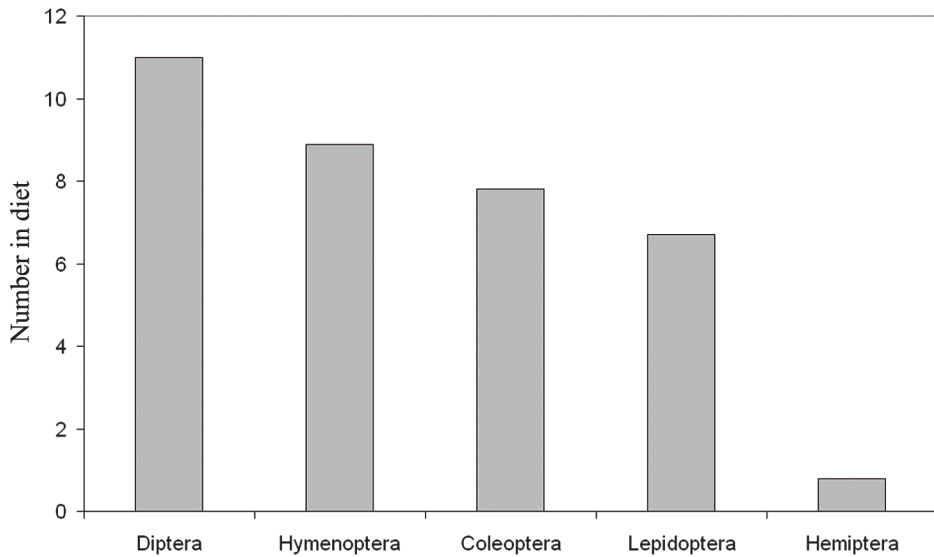


Fig. 4 Diet analysis

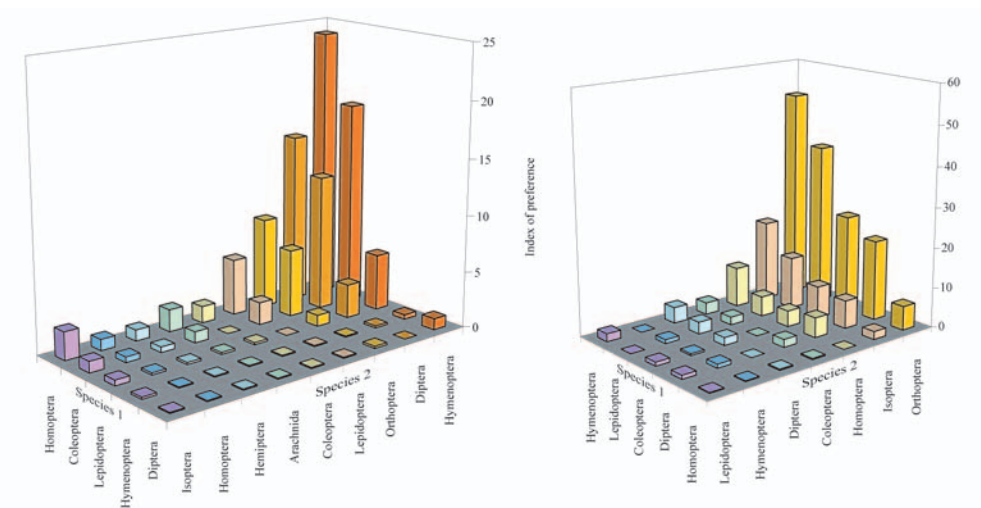


Fig. 5 Preferences from all data and from prey over 5.5mm

Transect data; traps and quadrats

Fig. 6 shows insect number and species number along the transect. Definite trends can be seen in these values but these need to be considered together with the diversity data below, which merges both elements. Shannon- Wiener and Simpson diversity indices were used to analyse both vegetation (Fig. 7) and insect data. Note that point 5 corresponds to the marsh area, which contains only trailing ground vegetation.

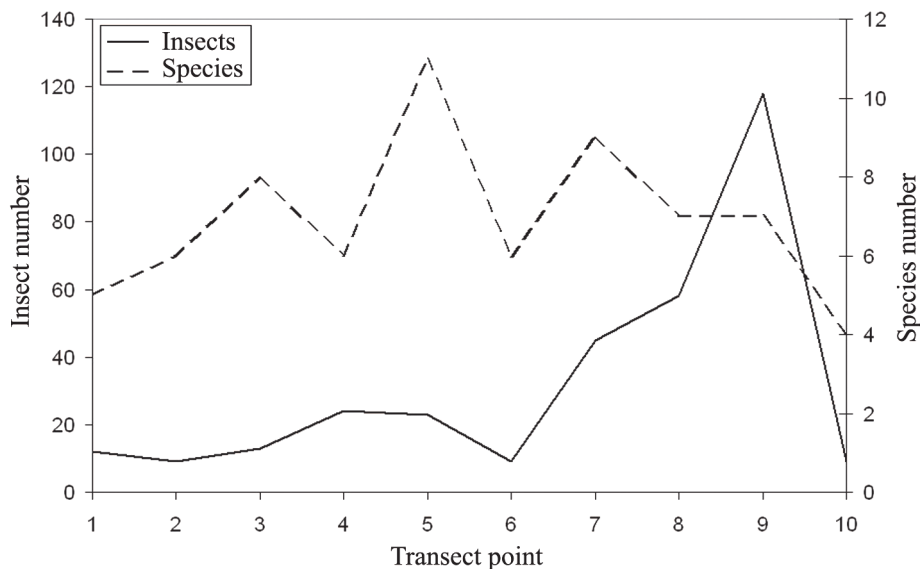


Fig. 6 Insect distribution (transect point 1 = coast, 5 = marsh, 10 = roost)

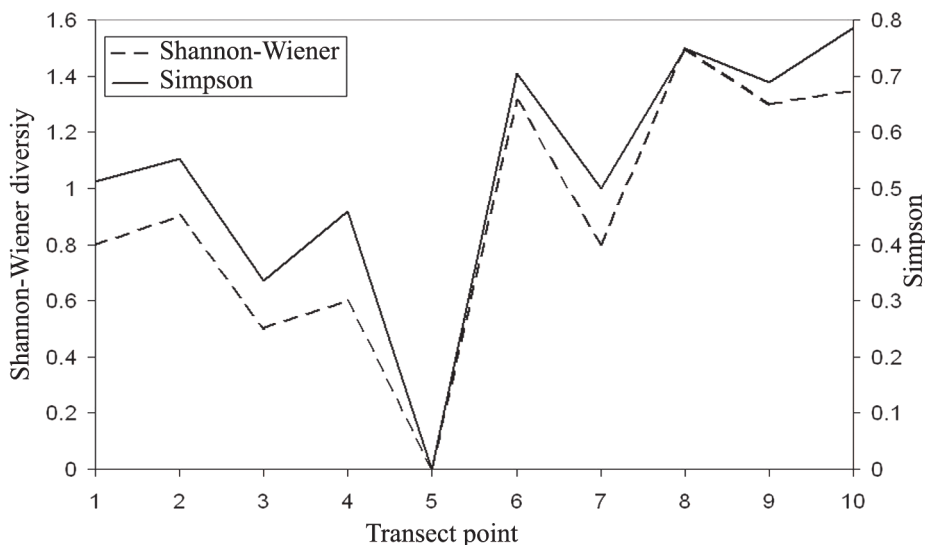


Fig. 7 Vegetation diversity

DISCUSSION

The echolocation surveys and surveys of caves are incomplete. Confirmation of the presence of *C. seychellensis* has been achieved but this represent only a fraction of the total area where it may occur.

The insect size data give a fair indication of the general pattern of distribution, especially when the two intermediate values. The 2mm class has highest frequency although this does not mean greatest number of species. It should be noted that the bulk of insects in that size class is composed of Hymenoptera (chalcids ?), and that these are from only a few traps. Basic theories of community structure and niche space produce such distributions; thus it could be assumed that the observed pattern is a suitable approximation of the actual distribution. A characteristic feature of the Seychellois insect fauna is their small size, so skewness towards lower values would be expected. SCOTT (1933) noted such a pattern, attributing it to the remote oceanic island effect. As a resource base for an insectivore, we thus find that even initially there must have been a tendency for small insects.

The effect of successional changes on size distribution also needs to be considered. If BROWN's (1984) sequence of events holds true, then a shift in size towards smaller species, would have to be accepted. However, to assume a downward shift in size is to assume that the new vegetational composition has provided a release mechanism for the smaller species, most of which are endemic. This general shift however need not occur because not all guilds are equally affected (SOUTHWOOD *et al.* 1982). Insect distribution could also be affected by a general depression of the abundance curve, i.e. reduction of diversity across the whole range of values. This effect would fit in well with a model which considers reduction in all plant associated insects (including phytophages) as a result of host plant loss. Such insects follow lognormal patterns and their removal will have consequences for all classes.

A size limit has been added to the distribution not only as a measure of detection efficiency but also to stress the importance of prey quality. It shows that the generalisations about abundance of tropical insects, and in the case of abundant prey for bats (HAILS 1982), may not hold true for *C. seychellensis*. The absolute value for the size limit may be an underestimate as maximum vocalisation frequency lies lower than 50kHz.

MOHL's (1988) equation for size detection however is derived from laboratory measurements, thus there should be some allowance for error in replication in the field. Nonetheless it should be appreciated that a size limit exists, which bars *C. seychellensis* from utilising all of the prey present. Size distribution alone gives the impression that the odds of acquiring sufficient food are stacked against the predator in this case. However, although less than 4% of the prey are available to the predator, this small percentage contains over 50% of the biomass.

Biomass content is a limiting factor imposing its own limits on size classes utilised. Optimising energy expended in foraging and energy gained for each capture should thus entail the capture of very large prey, but it should be remembered from the distribution that the probability of encounter of large prey is small. The frequency of large prey should thus tail off, not because of detection but because of prey scarcity. Optimisation of biomass gain itself implies indiscriminate capture of all prey species present, but each species has its own susceptibility to capture (take for example the response of arctiid moths and lacewings) and furthermore bats may actively select for certain prey species using cues other than signal strength.

The 5mm mark represents a region whereby gain in biomass per capture starts to rise more rapidly. It shows that a detection limit set at that value does not present a special problem for *C. seychellensis* as long as there are sufficient captures to offset energy

expenditure. The size and biomass content of each insect taxon has implications on its utility. In biomass terms Diptera appear to present the best option, but size limits their utility. With biomass and size combined (Fig. 3), the orthopterans and coleopterans present the best option. Orthoptera may not represent a stable fraction of the aeroplankton: cockroaches may fly frequently but the other members of the group (crickets etc.) appear to be mostly sedentary. This leaves Coleoptera, Lepidoptera and Diptera as important food items, a condition which is reflected in the diet results.

From Table 2 it can be seen that the percentages of insects present are not reflected in the diet. Diptera and Hymenoptera are less than expected and Lepidoptera and Coleoptera more than expected. Preference testing indicate that avoidance of Diptera and Hymenoptera appear only because all species are being considered together. They are common but small, thus it may not be outright rejection but rather their unavailability which gives rise to such values. Rejection of those common orders would indicate a highly specialist predator, a strategy which would most likely be unsuitable for an aerial insectivore. When considered in terms of a size limit (Fig. 5), a general reduction of extreme preference values is observed amongst the commonly eaten species (Diptera, Coleoptera, Hymenoptera and Lepidoptera). These indicate that the issue of restriction/selection for larger prey is but may be only a result of size distribution. A notable relationship is the higher selection for all orders over Orthoptera. This confirms that orthopterans, because of their habits may be unavailable as a prey resource. Possible errors in this interpretation may arise from miscounting individuals in faecal matter. Fragments present in the faeces indicate that *C. seychellensis* may cull certain parts of prey which means that diagnostic parts for certain taxa, e.g. coleopteran elytra, may be lost. Also certain species may provide comparatively more, and more readily identified fragments, e.g. Lepidoptera, which could lead to overestimation. Isoptera may be one of the orders presenting such a problem as they are soft bodied and readily shed their wings, leaving few hard parts for identification.

Interpretation of the preference results could lead to two different conclusions. Habitat requirement may be determined by the preferences expressed in the results. Thus it could be predicted that *C. seychellensis* would forage over habitat rich in the preferred species. A second interpretation would be that the preference values are the product (not the cause) of foraging over different habitats, which means that specific selectivity is not occurring. To obtain null values for preference *C. seychellensis* would have to forage over all habitats, a proposition which goes against optimal foraging. BRIGHAM (1992) encountered a similar effect in *Myotis yumanensis*, whereby dietary composition reflected swarm composition over the predominant foraging sites. Thus the second interpretation provides a simpler explanation which fits in with assumptions about foraging and also makes sense in light of the data limitations. NEUWELER & FENTON (1988) classifies bats such as *C. afra* (long narrowband calls, shallow FM, high wing aspect ratio), as species which feed mostly in open areas, but this is not a strict classification and deviations may occur. From the field observations and the above classification it could be inferred that *C. seychellensis* also forages above canopy height, but this does not take into account the quality of each site and the effect it may have on foraging.

Time constraints during the sampling period meant that habitat characteristics could not be analysed in any great detail. This affects the significance of conclusions drawn, especially those about spatial distribution of prey. The conclusions should thus be

taken as preliminary, and may need to be reviewed after further research. An attempt was made to measure success over different habitats by monitoring PM sweeps, which indicate interception. All results were rejected however because it was found that the emission of PM sweeps did not necessarily indicate successful capture; the reason being that in certain cases the rate of emission would have to be taken as indicating negligible handling times. Observations of feeding bats suggest that *C. seychellensis* has a preference for the coastal zone, feeding mostly over marshland. Foraging over hillside vegetation was not sustained and covered larger areas, although the hillside has much higher insect numbers, that in itself is not sufficient due to low prey quality. The preferred foraging sites actually correspond to the zone of highest insect diversity. Concentrated feeding within that zone thus indicates that *C. seychellensis* may be an opportunistic predator rather than one which shows prey preference. Utilization of prey within that zone would entail deviation from classifications such as NEUWELER & FENTON's. However this is not indicative of a misclassification, but instead it demonstrates flexibility in the foraging habits of the bat.

A combination of factors including marshland and open ground vegetation may be the cause of such a high diversity. A negative correlation between vegetation and insect diversity were obtained from the data (product moment correlation; Shannon = -0.8, Simpson = -0.7). These values are not necessarily significant as the vegetation data are from two different zones, each with its distinct composition and diversity. Accepting the correlation values reinforces the view that insect diversity increases from the hill to the coast in agreement with earlier work on altitude and insect diversity which has found in many cases there are low and mid elevational peaks in insect diversity (McCOY 1990). Existence of such diversity peaks leads to questions about what their importance is to *C. seychellensis*, and whether such trends have been altered by human activities.

The drop in insect diversity on moving up from the coast corresponds to the occurrence of secondary vegetation. A natural drop in the diversity of aerial insects may be present due to several factors (e.g. different habitat, windier), but it would be of interest to see whether such a trend has been accentuated by the vegetation. An order whose diversity could be used as an indicator is the Coleoptera, which represent important prey items in the recorded diet and also in terms of biomass and size. SCOTT (1933) reported over 80 species of Coleopterans as being directly associated with, or frequenting palms and other endemic plants. Loss of such plants would mean loss of many Coleopterans, but a simple cause and effect relationship with the decline of *C. seychellensis* may not necessarily be an appropriate description.

Island Biogeography Theory (WILLIAMSON 1983) raises questions as to why equally volant insectivorous bat species are not present in the granitic islands although *Traienops furculus*, *Chaerophon pusilla* and *Taphozus mauritianus* are said to occur on Aldabra (RACEY & NICOLL 1984). It can be argued that niches exists on the granitic islands which could sustain *Coleura seychellensis* but have barred other vagrants from establishing a foothold, or *C. seychellensis* that it represents a remnant population isolated as a result of geologic and sea level changes. *C. seychellensis* is present at very low densities on Mahé, but appears to be at slightly higher densities on Silhouette. If a population like that observed at La Passe (Silhouette) is present in all areas, then it can be concluded that a small but viable population is still present on Silhouette. The fragmentation and low population on Mahé raises doubts as to the prospects of breeding and therefore future survival of *C. seychellensis* on that island. A general lack of information on the surviving

population appears to be hampering any effort to set up conservation programmes for the species.

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A behavioural study of the Silhouette sheath-tailed bat (*Coleura seychellensis*)

HELEN BURGESS¹ & NICOLAS LEE²

¹ Birch House, Courtmead Road, Cuckfield, West Sussex RH17 5LR, U.K.
[helbelmel@hotmail.com]

² 10 Ravenshead Close, Selsdon, South Croydon, Surrey CR2 8RL, U.K.
[nicolaslee82@hotmail.com]

Abstract.— The behaviour of the Seychelles sheath-tailed bat *Coleura seychellensis* was studied in the largest known roost of the species at La Passe, Silhouette island. The population of bats using the roost numbered 32, the highest count recorded for the species. The roost comprises two small interconnected caves in a boulder field. The preferred roost was relatively dark and cool. Individuals appeared to show preferences for positions within the roost. A harem structure has been speculated to exist in this species, observations from the present study may support this but are inconclusive.

Keywords.— Seychelles, Chiroptera, Emabllonuidae

INTRODUCTION

The Seychelles islands support one Critically Endangered species of mammal; the Seychelles sheath-tailed bat *Coleura seychellensis* PETERS, 1868. This species was described as “very common in the neighbourhood of the town of Port Victoria” (WRIGHT 1868) but is now rarely observed. A small number of roost sites have been located for this species but by 2003 all have been reported to be abandoned with the exception of two interconnected caves on Silhouette island occupied by 10–15 bats. The causes of this decline are not known, human disturbance, predation by barn owls and habitat destruction have been suggested (NICOLL & SUTTIE 1982; RACEY & NICOLL 1984; GERLACH 1997). Pesticide contamination does not appear to be a significant threat. The existing Silhouette roost is secure from human disturbance but invasive creepers threaten to smother the entrance. There is a need to eliminate this threat and determine the ecological requirements for the species. Very little is known of the Seychelles sheath-tailed bat and there have been few published studies of its behaviour (NICOLL & SUTTIE 1982; MATYOT 1995; JOUBERT 2004), in addition to this a brief study was made of the La Passe roost on Silhouette in 2001 (see Appendix I). The present study is the first in depth study of behaviour in the roost on Silhouette

METHODS

Observations at the roost were made on each of the 4 days of the investigation (31st March - 1st April 2003) for ½–2 hours up to 3 times a day. The observation timetable covered as many different times of the day as possible; previous studies indicated the need for more observations to be made at dusk and dawn so studies concentrated around 6am when it was just starting to get light and 6pm when the light began to fade; latest observations started at 9pm. Two observers were divided between the 2 roosts. While

approaching the roost a bat detector was used to determine whether or not the bats were present.

Light intensity (in Lux), temperature and relatively humidity were recorded inside and outside the roosts using a light meter and a whirling hygrometer. The temperature, humidity and light level recording point in roost A was directly beneath the main roosting point, consequently it was sometimes not possible to record climatic data due to the presence of roosting bats. In roost B bats were always present and data were recorded in the cave entrance.

Observations involved viewing the bats, recording all behaviour and numbers in the groups. The time of the behaviour was also recorded. At cave A this was done by viewing the bats through the openings into the cave on the left and right side. Observations into cave B proved more difficult as the entrance to the cave was covered by a boulder 1.7m in height which had to be scaled to gain a good viewing position. During dark periods of observation a torch was used. However, this was kept to a low level as it aggravated the bats and so caused unnatural behaviour.

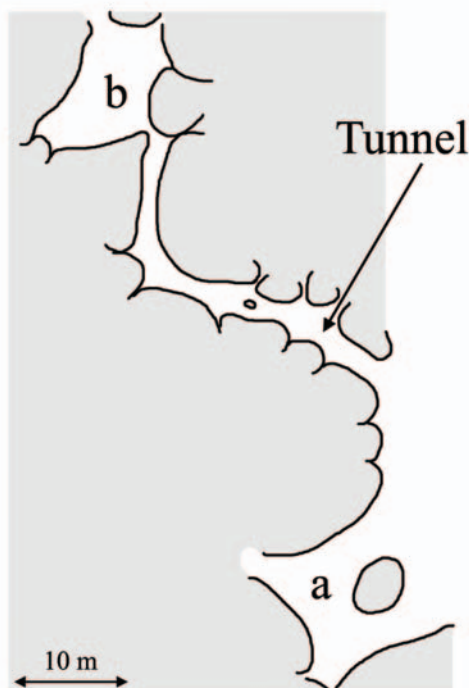


Fig. 1 Tunnel between roosts

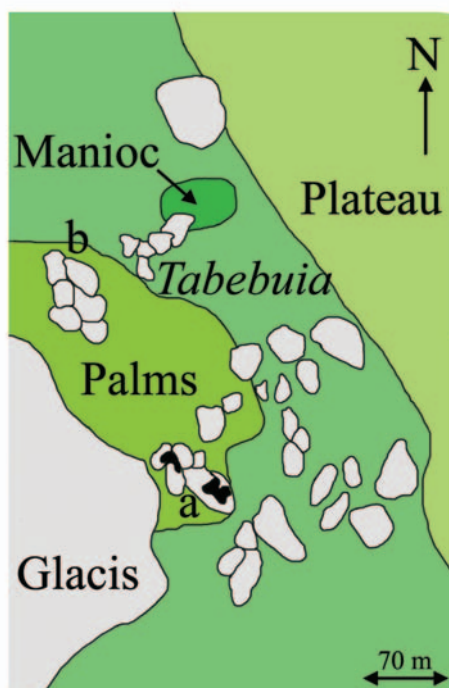


Fig. 2 Map of the La Passe roost

RESULTS

Roost characterization

The caves are in a boulder field of eroded granite boulders, situated in a forest of mixed native and introduced palms with cinnamon trees also present. These trees provide

a medium density vegetation cover (60% cover) directly outside the entrance to the caves. It is reached by a steep path over large granite boulders, to an altitude of 44m (± 24 m, GPS reading). The beginning of the path is well concealed. The roost system is comprised of two caves: cave A is seen first in a small clearing at the top of the path and cave B is only accessed through a small tunnel, formed by granite boulders (Figs. 1 & 2).

Cave A is separated into two parts by a central boulder. At the far left-side there is a side exit to an enclosed arrangement of boulders.

Table 1. Measurements (m) of the La Passe roosts, data for roost B are estimated

	Roost A		Roost B
	left	right	
Height at entrance	3.1	1.8	3.5
Width of entrance	2.1	3.8	2.0
Maximum depth	9.7		5.0
Roosting position on ceiling to floor	1.4	2.5	3.5
Entrance of cave to roosting position	2.1	3.8	3.0

Numbers

On the second day of observations a count of 32 bats was made in cave B from a viewing position of about 1.5m away. This was followed the next day by another count of 31 bats (Fig. 3).



Fig. 3 Bats in roost B

Vocalisations

Ultrasounds of 24-26KHz were detected at different times of the day in both cave A and B. While bats flew in and out of the entrance to cave A on two separate occasions (29th March 6:05am and 31st March 6:00am) they produced ultrasounds of higher frequencies, 28 and 29kHz respectively (Table 2).

Table 2. Vocalizations in the La Passe roosts

Date	time	Cave	Frequency (kHz)	observations
29 th March	06:05am	A	28	Very active, 4-8 circling in and out of entrance
	06:35am	B	25	
	10:52am	B	25	Single bat vocalizing
	17:00pm	A	26	
30 th March	09:30am	A	26	Little vocalization
	09:54am	B	26	
	18:39pm	B	25	All bats in a settled, roosting group
31 st March	06:00am	A	29	Very active, 2-3 circling in and out of entrance
	15:35pm	B	24	
1 st April	09:30am	B	24	All bats roosting in a group
	18:15pm	a	25	

Behaviour

A total of just over 11 hours were spent observing the bats. A number of behavioural patterns were observed:

Circling in and out of cave A entrance.— This occurred on 3 occasions; twice at dawn (about 06:00hrs) and once at around 18:00hrs. On all occasions the bats were very active but remained relatively quiet.

Solitary Bat in cave A.— This occurred on four occasions, always during the day; mainly in the afternoon. The bat would be found at the beginning of an observation session alone in the cave or would remain after others had left the cave due to disturbance. This bat would sometimes be joined by a small number (4-5) other bats flying in from cave B

Movement from cave A to cave B through tunnel or into tunnel and then back to cave— This occurred at all times of the day and on all of the days of observation. At periods of dusk and dawn the bats would be found flying between the two caves via the tunnel. Movement through the tunnel to observation points proved that the bats were going right through to the other cave and not just turning around half way through the tunnel making it appear like new bats were returning to the cave. A number of bats would leave one cave

and fly to the other cave and on occasions a similar number of bats (not the same bats) would fly back to the cave from the other cave soon after. During the day this movement of bats between caves was less frequent. The bats use more than just one route to travel between both caves. On numerous occasions, they were seen flying out of the entrance to cave A and up over the trees before turning in the direction of cave B. There are also at least two other alternative routes within the tunnel itself. On both arrivals at dawn, the bats were at their most active. At 6am, when it was just starting to get light, a number of bats would be roosting in cave A and cave B with many more flying to and fro between the two caves using mainly the tunnel. It would take at least an hour for the bats to settle in either cave and by light the activity was greatly reduced. At the end of the dusk observation period on 30th March (19:10hrs), no bats were roosting in either of the two caves.

Distribution within roost.— During the observations the majority of bats stayed in cave B where during the day they would usually formed one large, tightly packed group (attached by all four limbs) towards the back of the cave and another group made up of 3–4 bats slightly spread out (hanging mainly by two limbs) towards the front of the cave and the tunnel. The group at the front would contain a single bat that would constantly vocalize even when no other bats would reply. This bat would also take to flight around the cave from time to time sometimes landing amongst the main group of bats. Loud and agitated vocalisations would be given off by other members of the group when this occurred. They would also sometimes return vocalisations. The bats in the group closest to entrance in cave B appeared to be substantially rounder than those in the main group.

Fighting for position on the roost.— On a number of occasions the bats in cave B would take to flight around the cave for periods of between 20secs and 5mins around the cave. On landing the group would be spread across the ceiling. A period would then follow when the bats would move closer to each other and begin to pull each other closer using their front limbs. Vocalisation would also accompany this periods with bats sometimes taking to flight before landing again at nearly the same point the ceiling. This jostling for position was a common theme amongst the bats.



Fig. 4 A single Seychelles sheath-tailed bat

Roosting.— During the day the majority of bats would roost by all four limbs. In the majority of cases they preferred to roost with company and to be in contact with them. This is similar to observations made by NICOLL & SUTTIE (1982). They tended not to roost upside down, but instead pressed their underside against the cave ceiling while hanging on by all fours with their wings outstretched (Figs. 3 & 4). Occasionally, they would roost on top of each other in clusters.

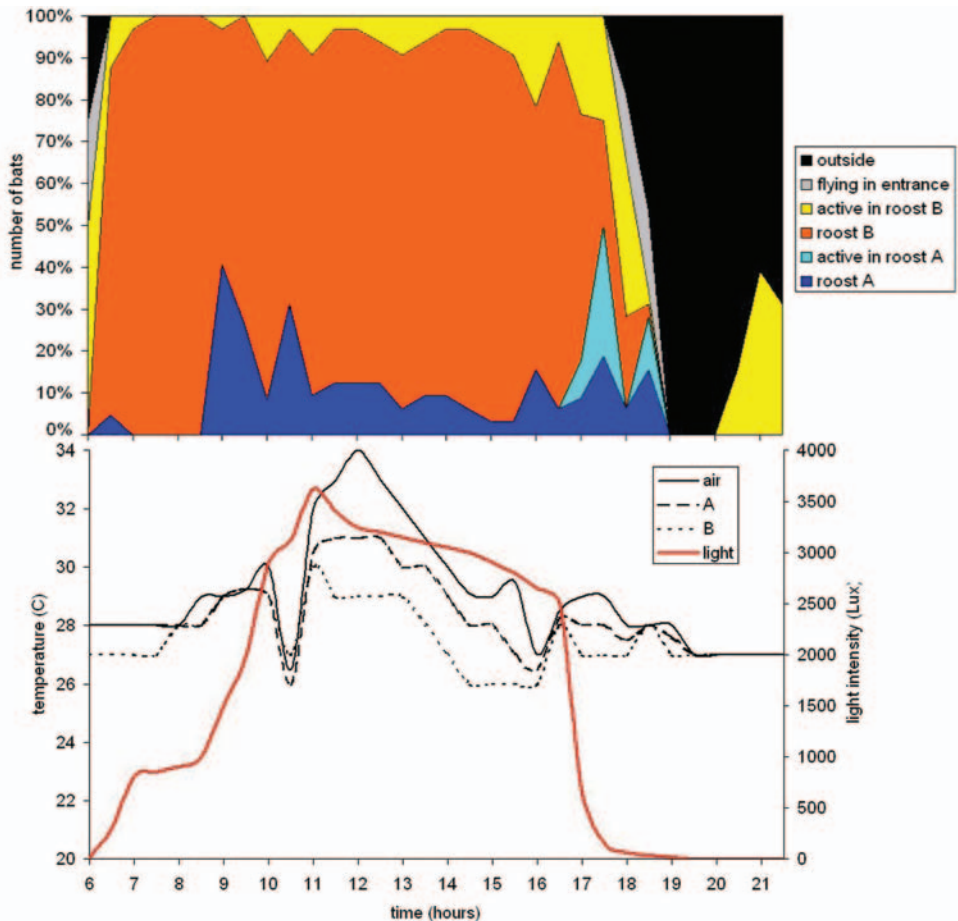


Fig. 5 Behavioural patterns and climatic data

Climate

Cave A receives more light and is warmer than cave B (Fig. 5) and the bats tended to spend most of their time in cave B. For example, readings taken on 29th March at 10am outside the caves showed cave B to be 2°C cooler than cave A and a light reading 2400 Lux lower. Four observational periods coincided with heavy rainfall, cloud and an increase in wind speed. On 3 out of 4 occasions activity of at least some bats was increased.

DISCUSSION

Cave A and B were linked by a tunnel which was used by the bats to get between the two caves. Prospecting was done around the La Passe site for other possible caves and passages between them. Unfortunately none were found. However, from the direction flown by the bats on leaving the roosts and on one occasion at dusk the bats leaving cave B, but never getting to cave A it can be strongly suggested that there are more roosts at the La Passe site or close by, although these may be only temporary roosts (see Fig. 2).

During the day, the bats preferred to roost in cave B where it was cooler and darker. It is also more protected by surrounding boulders and vegetation and so the bats are less exposed to predators and changes in the weather. Individuals appeared to have their own specific position within the roost.

The increased amount of vocalisation heard when members of the group entered a cave was a result of the new-comers attempting to locate this position and in many circumstances, displace other bats in order to roost. Cave A became more populated at dusk when the bats were preparing to feed. The entrance to cave A is in a small clearing in the forest and offers an easier route out. One bat was observed at 18:45hrs on 29th March circling a moth flying directly outside the left-side of cave A, but failed to catch it.

The difference in ultrasound used by the bats inside and outside the cave although only small is similar to the differences found by NICOLL & SUTTIE (1982). This also matches different levels of ultrasound that bats use when performing different activities such as foraging in dense vegetation foraging in open spaces and navigating in caves (NEUWEILER 2000). NICOLL & SUTTIE (1982) recorded a wider range of vocalization frequencies for bats flying in and outside of the cave: 35–40kHz for (compared to 28–29kHz in the present study) and an audible sound at 15–20kHz within the cave (compared to 24–26kHz).

Although it was not possible to distinguish between males and females the fact that no protruding external genitalia were visible may indicate that the bats were not in a reproductive phase. NICOLL & SUTTIE (1982) suggested that *C. seychellensis* could be polyoestrous due the presence of young bats in April in one year of their study. This study coincided with this period though no young were seen. However, the aggressive behaviour and loud vocalisation seen by a single bat roosting with 2–3 other larger bats, slightly away from the main group in cave B could be the sign of a protective male with pregnant females. This could be possible as these bats appeared larger than many others. This would also fit with the high frequency of vocalisation seen by NICOLL & SUTTIE (1982) and would also give support to the suggested a harem system (NICOLL & SUTTIE 1982).

The bats were more active around periods of bad weather. This matches the previous observations (in NICOLL & SUTTIE 1982); although no bats were seen foraging around the La Passe settlement area at these times, this activity is probable as insects are most abundant during bad weather.

The present study provided an accurate count of the bats and a preliminary account of their behaviour. Future research should aim to investigate the remaining questions over foraging behaviour and the existence of the harem system.

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APPENDIX I.

Summary of observations on the sheath-tailed bat (August 2001). NADINE CLARK

The sheath-tailed bat *Coleura seychellensis* was located in two roost sites (A and B) in granite boulder caves above La Passe, Silhouette. Roost A, although as large in size as roost B, only had a few bats present. This may be due to the lighter, more exposed opening of the first roost. A maximum of 4 bats were seen in roost A, forming two groups of two. The bats are found normally quite a way back into the cave in the darkest part. The bats seem to move between the two roost sites which may suggest that there is no set group occupying roost A. In roost B a maximum of 12 bats have been recorded at any given time. I would estimate the population of sheath-tailed bats, spread between the two roost sites, to be approximately 13. The bats roost in the second roost virtually in the centre of the cave approximately equidistant from the three openings. The pattern of distribution on the ceiling varied daily but the general trend was a main group in the centre of the ceiling consisting of at least 6 bats. Sometimes all the bats were in this main group, at other times two groups would form to the north-west of the main group. This group could consist of 1-4 bats. Often the main group formed a triangle or diamond shape with the extremities pointing towards the entrances to the cave. Both cave entrances were approximately north-west facing and fairly sheltered from the wind. The entrance to roost B is much more concealed than roost A which may account for the difference in bat numbers. The bats spent the majority of the time attached to the ceiling with just their hind feet. They were occasionally seen holding on with all four feet but this was rare. To move position within the colony (a frequent occurrence) the bats either flew and landed at the new position, often taking several attempts, or else moved across the ceiling on all fours. The bats were generally very vocal as they moved, as were their neighbours. These shifts in colony position often resulted in the neighbour the bat was moving towards, also moving. This could in some instances 'upset' the group to such an extent that the colony may all move position (generally by flight). Physical contact between bats was frequent and ranged from gentle nudging using their wings, to more aggressive behaviour with banging into each other as they swung backwards and forward from the ceiling. The bats also seemed to roost very close together at times so that it was difficult to discern any individual bat. In general two bats would huddle together virtually holding onto the same piece of rock and touching each other. This made estimating the number of bats incredibly difficult and may have led to an under-estimate of numbers. Physical contact generally coin-

cided with loud, complex, high-pitched calling. The bats were very vocal with normally only two minutes going by between calling. The maximum length of time of silence recorded in roost B was 8 minutes. The calling could last from 1 second to 8 minutes of continuous ‘chatter’ in the colony. Ultrasound was detected during some, but not all of the calling, at around 30-40kHz. The bats did not appear to react to outside noises whether they were mynah birds, fruit bats, falling stones or leaves. The only thing that could possibly upset them was the helicopter and possibly the sound recording equipment. From the short time of study it was not possible to distinguish the part of the day when they are at their most active or quietest.



Fig. 6 Bats circling outside roost A at dusk

The bats of Silhouette Island, Seychelles

JUSTIN GERLACH

PO Box 207, Victoria, Mahé, SEYCHELLES

133 Cherry Hinton Road, Cambridge CB1 7BX, U.K.

[jstgerlach@aol.com]

Abstract.— A review of the status of the bats recorded on Silhouette island is presented. This is placed in the context of the conservation status of the bats on the granitic islands of Seychelles. Two species are present: the Seychelles fruit bat *Pteropus seychellensis* and the Seychelles sheath-tailed bat *Coleura seychellensis*. The Silhouette population of the fruit bat is estimated at approximately 2,000 (with a Seychelles total of approximately 8,500). One roost of the sheath-tailed bat is known on Silhouette, this contains 32 bats. This is the only roost to have been monitored regularly and is only one of two known in Seychelles. The fruit bat population appears to be stable, the sheath-tailed bat remains Critically Endangered.

Keywords.— Chiroptera, *Coleura seychellensis*, *Pteropus seychellensis*, Seychelles

INTRODUCTION

The granitic Seychelles islands support only two species of native mammal, the Seychelles fruit bat *Pteropus seychellensis* MILNE-EDWARDS, 1877 and the Seychelles sheath-tailed bat *Coleura seychellensis* PETERS, 1868, both with naturally restricted

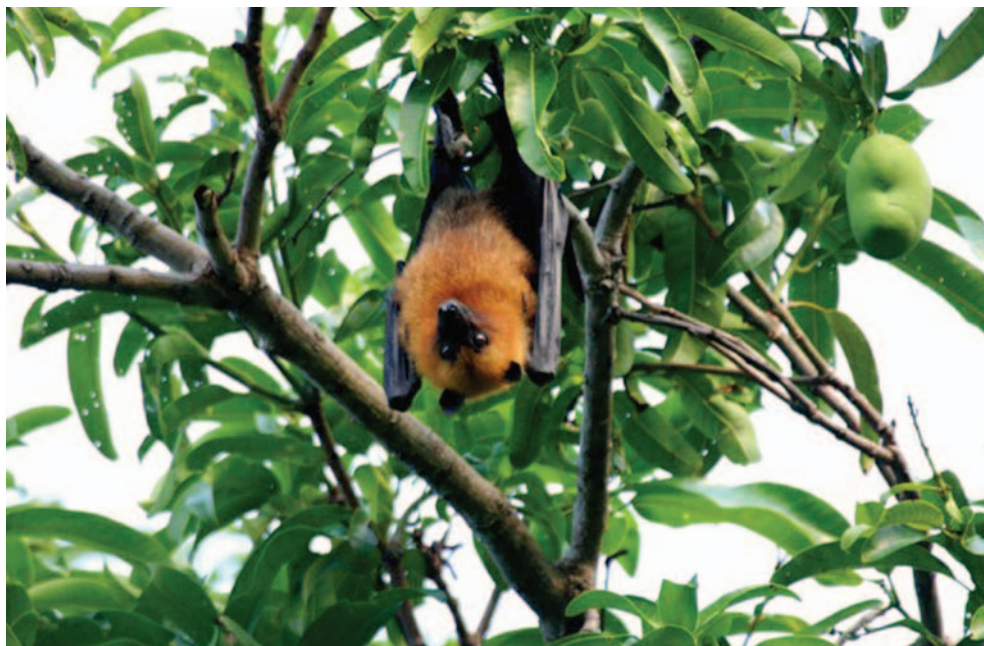


Fig. 1 *Pteropus seychellensis* on Silhouette (photo by N. BALL).

ranges. Distributions and populations have been further reduced by human activity; the Seychelles sheath-tailed bat is classified as Critically Endangered by IUCN.

The Seychelles fruit bat (Fig. 1) was estimated to number some 10,000 in 1979 and current populations are believed to be close to this level although adequate censuses have not been completed on all islands. Fruit bat populations have been assessed by roost counts on three occasions. In 1977 a survey of Praslin and neighbouring islands counted 2,052 bats and estimated the total to be approximately 2,500 on these islands (RACEY 1979). A repeat in 1979 counted 1,399 on Praslin and La Digue (compared to 1,443 in 1977). At the same time 2,463 were counted on Mahé and the total for that island estimated at 10,000 (RACEY & NICOLL 1984). In 1996 4,557 bats were counted on Mahé (with an estimate of over 4,000) and 1,229 were reported from Praslin and neighbouring islands. 200 were estimated to be roosting on Silhouette using a different methodology.

A 1992 review of the data concluded the species was not threatened but needed regular monitoring (MICKLEBURGH *et al.* 1992). Levels of consumption and other causes of mortality have been assessed in the past (MAISELS 1979; VERSCHUREN 1985; MELLANBY *et al.* 1996). Social behaviour was described in 1979; mating has been recorded in June–July, with births in November–December (RACEY & NICOLL 1984), after which family territories are formed within the roost. In April juveniles aggregate in the centre of the roost, with the males and females separating. No data are available for the non-communal roosting population on Silhouette. The diet is known to comprise sweet soft fruits and nectar, with 23 fruits identified and 4 flower species (RACEY & NICOLL 1984).

The Seychelles sheath-tailed bat (Fig. 2) has been recorded as a resident species on the four largest islands of the Seychelles group. Two subspecies have been described: *C. s.*

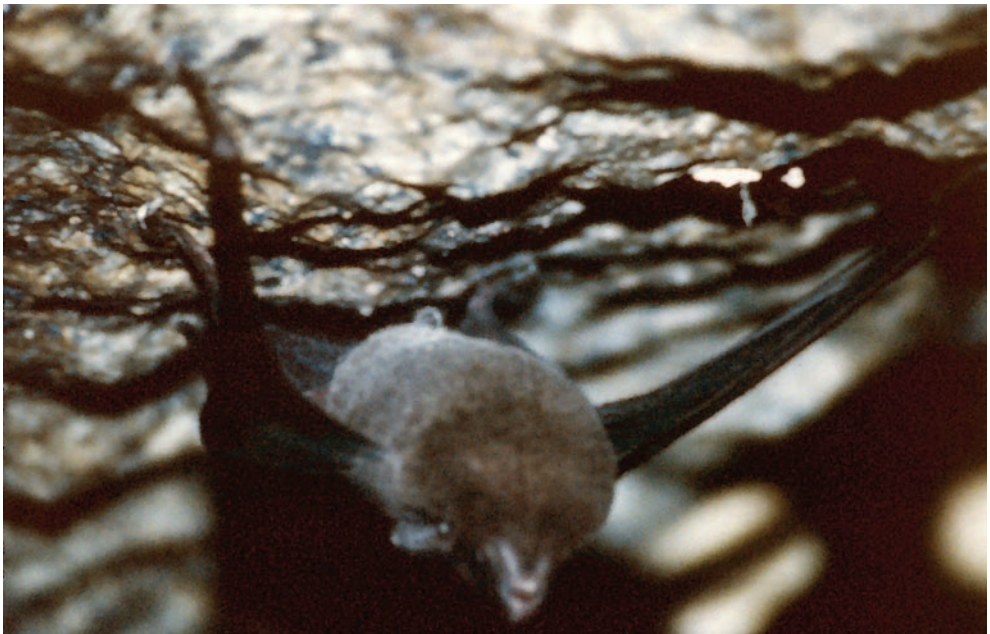


Fig. 2 *Coleura seychellensis*

seychellensis from Mahé and Praslin and *C. seychellensis silhouettae* (THOMAS, 1915) from Silhouette and La Digue (HILL 1971). The island origins are based on unsubstantiated statements and limited metric data in NICOLL & SUTTIE (1982) (Table 1). In the granitic islands roosts have been recorded on all 4 islands. The species was first recorded in 1868 when roost sites were noted to have north-facing entrances screened by palm

Table 1. *Coleura seychellensis* biometrics (from THOMAS 1915, NICOLL & SUTTIE 1982 and new data). Institutional abbreviations: BMNH – British Museum (Natural History); UMZC – University Museum of Zoology, Cambridge

Specimen or reference	sex	Origin	Forearm	Skull	Maxillary tooth row	p^4-m^3	Live weight (g)
BMNH 69.2.19.2	M	Mahé ?	56.0	15.2	7.0	5.0	
BMNH 83.8.6.1	M	Mahé ?	57.0	15.3	7.0	5.0	
BMNH 76.10.10.1	F	'Zanzibar'	56.6	15.1	6.8	5.0	
BMNH 6.3.18.2	M	Silhouette	53.0	14.4	6.5	4.7	
BMNH 6.3.18.3	M	Silhouette	52.5	14.7	6.7	4.7	
UMZC	F	Mahé	57.0	-	-	-	
NICOLL & SUTTIE 1982	M (n=6)	La Digue	53.9±0.2	-	-	-	10.2±0.1
NICOLL & SUTTIE 1982	F (n=5)	La Digue	55.6±0.3	-	-	-	11.1±0.3



Fig. 3 Female *Coleura seychellensis* collected at Cascade on Mahé in 1913 (UMZC)

leaves (WRIGHT 1868). A small number of individuals were collected in the late 1800s and early 1900s (Fig. 3) but there were no further published records until one was shot in 1908 in an attempt to locate parasites (SCOTT 1914).

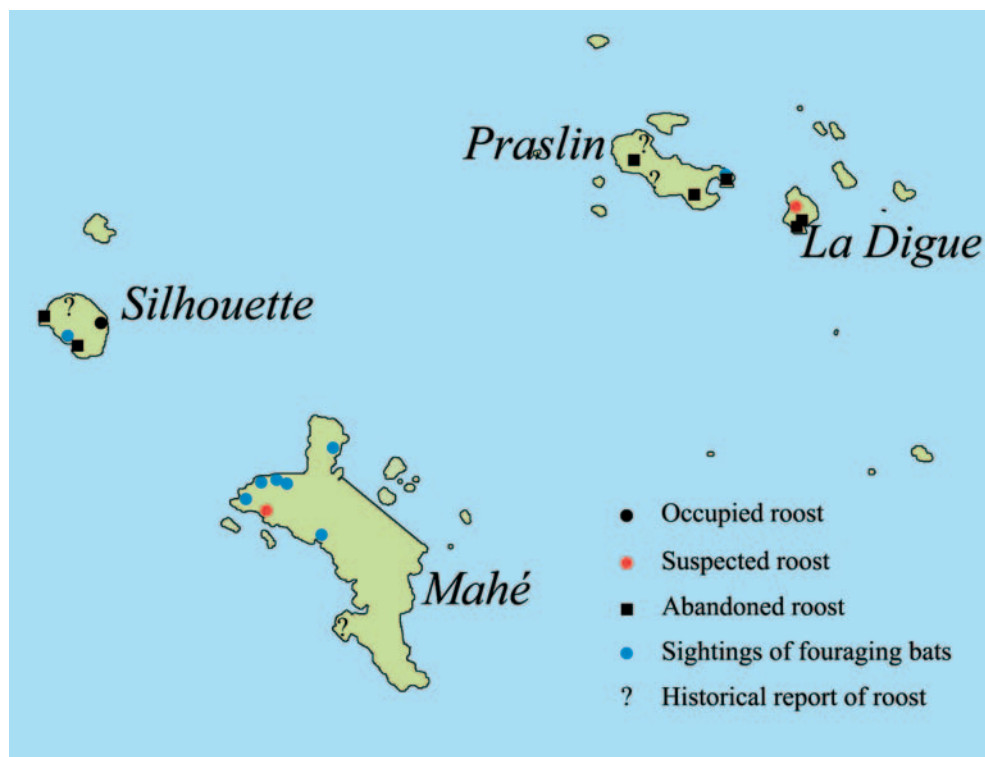


Fig. 4 Map of *Coleura seychellensis* distribution.

Research in 1973–1980 located 5 roost sites (2 occupied) and monitored occupancy (CHEKE & DAHL 1981; NICOLL & SUTTIE 1982; RACEY & NICOLL 1984). Numbers of roosting bats were low (1–6 in most roosts, rising briefly to 12 in one roost). Since 1991 (MELLANBY *et al.* 1996) all these roosts have been reported to have been abandoned for unknown reasons. These investigations provided some data on roost sites, social behaviour and reproduction. It was reported that a single male harem system existed and that pregnant bats were observed in November and flying young in December/January (NICOLL & SUTTIE 1982). The presence of juveniles in April suggests that two breeding seasons may occur. It was suggested that this species feeds in or above the forest canopy (NICOLL & SUTTIE 1982) although brief observations in 1993–4 indicate that at least some feeding is done within 2m of the ground (MATYOT 1995). In 1995 further abandoned roosts and the occupied roost on Silhouette were found. It was reported that Coleoptera and Lepidoptera were the main food items identifiable in guano, prey items were estimated to be above 5.5mm long (MATYOT 1995; JOUBERT 2004). Roosts and foraging bats have been recorded in several areas (Fig. 4). The roost on Silhouette has been monitored

since 1995 (Seychelles Division of Environment [DoE] 1995-7, The Nature Protection Trust of Seychelles [NPTS] quarterly from 1997). The location of this roost has allowed observation to be made without disturbance (BURGESS & LEE 2004), results of the monitoring for both bats species on Silhouette and the research into the sheath-tailed bat are summarised below.

METHODS

Seychelles fruit bat

4 surveys of the fruit bat populations have been published, dating from 1977 to 1996. These surveys were based on roost counts on different islands, few of the surveys have significant overlap and none visited all islands. The published results are compiled here. Only one survey included Silhouette island; this did not locate any roosts and this estimated the population at 200 bats based on causal observations.

In 2001-2004 visits were made to all of the granitic islands, bats were not counted on all islands but their presence was noted and counts made on the smaller islands. Attempts were made to refine the population estimate for Silhouette on two occasions. In July 1999 a transect method was used, recording bats 3m either side of paths in four principal habitats: coastal forest, lowland forest, palm forest and moss forest. This provided an estimate but initial calculations (NPTS 1999) were based on incorrect area calculations, these are corrected below (Table 2). In April 2004 vantage points were used to count bats at 8am in different areas. The areas that could be observed were drawn onto a map and the ground area calculated, providing density estimates of active bats in different habitats. Searches

Table 2. Fruit bat populations on Silhouette (estimates and 95% confidence limits)

Habitat	area (ha)	1999		2004	
		density (per ha)	population	density	population
Littoral	4	0	-	0	-
Marsh	12.1	0	-	0	-
Suburb	17.6	0	-	0	-
Casuarina	1.5	0	-	0	-
Dry coastal	5.7	2.89±1.43	16±8	0.01±0.01	0
Mixed coastal	92.2	3.10±2.91	286±268	0.11±0.05	10±5
Coffee	8.4	0	-	0	-
Hevea	7.4	0	-	0	-
Glacis	112	0	-	0.01±0	1±0
mid-altitude	351.4	1.45±0.25	510±88	0.11±0.04	38±14
Palm	1087.5	1.05±0.45	1,142±489	1.67±0.10	1,813±109
Dicranopteris	70.3	0	-	0	-
<i>Clidemia</i>	2.3	0	-	0	-
<i>Cyathea</i>	0.7	0	-	0	-
<i>Pisonia</i>	0.5	0	-	0	-
mist	215.3	1.42±1.40	306±301	0.10±0.05	22±11
TOTAL			2,260±1,154		1,884±139

for bats in closed forest indicated that 20% of bats were active at this time of day, enabling a total population estimate to be made.

Seychelles sheath-tailed bat

The La Passe roost is described in BURGESS & LEE (2004). The numbers of bats in roost A were recorded at least quarterly since 1997 and roost B since 2001. Both roosts A and B were entered when the bats had left the roost to forage at 19:00hrs on 8th and 14th June 2004 (BURGESS & LEE 2004). A search was made for fresh guano but only 16 faecal pellets were located in roost A. On 14th June plastic sheets measuring 30x40cm were placed over the main accumulations of decomposed guano and left for 24 hours. Fresh faeces were collected on these sheets. These were weighed fresh and stored dry until examination.

The dried faeces were moistened with water and dissected under a binocular dissecting microscope at $\times 10$ and $\times 20$ magnification. All arthropod remains were identified as completely as possible and counted to obtain an indication of the number of items consumed. Moth scales were present in almost all samples, these were recorded but not counted. The data were combined with a smaller set of samples collected from roost A on 13th July 1999. Searches for further roosts have been made around the coast and along mountain paths since 1997.

RESULTS

Seychelles fruit bat

Fruit bat population estimates on Silhouette are summarised in Table 2, the most recent estimate is incorporated into the overall summary (Table 3).

Table 3. Seychelles fruit bat census data. (1977-79: NICOLL & RACEY 1981; RACEY 1979, 1996; MELLANBY *et al.* 1996)

		1977-9	1996	2001-4
		Islands	group	
Mahé group			10,000	5,000
	Mahé	2,463	4,557	+
	St. Anne	-	0	20
	Therese	-	-	+
Silhouette & North		-	?	2,000
	Silhouette	-	200	1,884
	North	-	-	+
Praslin Group			2,500	1,400
	Praslin	1,399-1,443	800	+
	Arde	-	42	0-40
	Curieuse	0	0	+
	Round	-	-	70
	Cocos	-	-	30
	Felicite	170-500	-	50
	Marianne	-	-	10
	La Digue	439	387	+
Fregate		-	0	100
TOTAL			>12,500	>6,000
				8,500

Seychelles sheath-tailed bat

The La Passe roost on Silhouette has passed through a period of decline in 1996 and a recovery since 2001. These changes may be associated with changes in the surrounding environment. When first visited in 1995 the plateau near the roost was largely open grassland under coconut plantation. At this time bats were recorded feeding mainly around the marsh (JOUBERT 2004). In 1996 cinnamon bark harvesting occurred near the roost and this was thought to represent a disturbance risk and a habitat alteration (DoE 1996), cropping of cinnamon has not occurred near the roost since that date. At this time a copra dryer was also in operation on the plateau and smoke from the dryer was found to be entering the roost in 1997. The copra dryer ceased to function in 1998 and since that date no disturbance has occurred at the roost. Coincidental with this, vegetation management has been carried out to prevent invasion of alien tree species (principally *Cinnamomum verum* and *Tabebuia pallida*) and creepers (*Pueraria phaesaloides* and *Passiflora foetida*) around the roost. Increases in the number of bats in the roost may be associated with this reduction in disturbance and improvement in vegetation. Plateau vegetation has also changed, with an increase in tree cover and denser marsh-fringe herbs and shrubs. The marsh foraging pattern reported from 1995 (JOUBERT 2004) no longer appears to be significant.

The collection of faeces in roost A was not successful, this was probably due to the dispersed distribution of bats in this roost. 365 samples were collected in roost B. The contents of the faeces are summarised in Fig. 5 and Table 4.

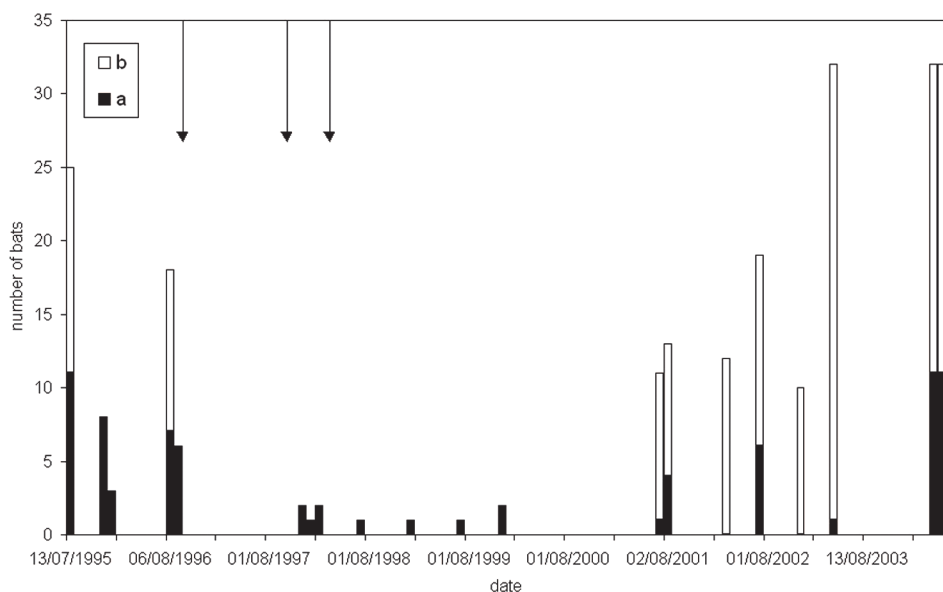


Fig. 5 Contents of *Coleura seychellensis* faecal samples from the La Passe roost and comparison with aerial insect abundance in different habitats.

Table 4. Contents of *Coleura seychellensis* faeces from the La Passe roost, Silhouette

		13/7/99 (n=4) Roost A		6/2004 (n=16) Roost A		6/2004 (n=200) Roost B	
		sample	n	sample	n	sample	n
Lepidoptera							
	scales	4	?	9	?	170	?
	medium leg	4	24	9	15	7	7
	small leg	0	0	0	0	4	4
	TOTAL	4	24	9	15	181	?
Dermaptera							
	<i>Labia</i> sp.	0	0	0	0	1	1
	earwig?	0	0	0	0	2	2
Coleoptera							
Chrysomelidae	Cassidini larva	0	0	0	0	1	1
Curculionidae	<i>Cratops segregatus</i>	0	0	0	0	7	7
	<i>Cratops griseovestitus</i>	0	0	0	0	20	20
	Sp. 1	0	0	0	0	1	1
	<i>Rhyparidula seychellensis</i>	0	0	0	0	3	3
Oedmeridae		0	0	0	0	12	12
Family ?		4	6	3	4	3	3
	TOTAL	4	6	3	4	47	47
Hymenoptera							
Braconidae		0	0	0	0	21	45
Cynipidae		0	0	0	0	1	1
Chalcidae		0	0	0	0	2	2
Formicidae	<i>Monomorium floricola</i>	0	0	0	0	1	1
	<i>Pheidole megacephala</i>	1	1	0	0	0	0
	<i>Technomyrmex albipes</i> (alate)	0	0	0	0	2	2
	<i>T. albipes</i> (workers)	0	0	3	4	0	0
	<i>Tetramorium simillimum</i>	0	0	0	0	6	6
	TOTAL	1	1	3	4	33	57
Isoptera		0	0	0	0	2	2
Diptera							
Chironomidae	Sp. 1	0	0	0	0	2	2
	Sp. 2	0	0	0	0	1	1
Muscidae	<i>Mydaea mediana</i>	0	0	0	0	1	1
Psychodidae		0	0	0	0	1	1
Scatopsidae		0	0	0	0	2	2
Tipulidae		0	0	0	0	2	2
	TOTAL	0	0	0	0	9	9
Orthoptera							
Gryllidae		0	0	0	0	1	1
	<i>Zarceus fallaciosus</i>	0	0	1	1	0	0
	<i>Lobopterella dimidipes</i>	0	0	1	1	3	3
	TOTAL	0	0	2	2	4	4
Hemiptera							
Lygaeidae		0	0	0	0	1	1

DISCUSSION

In 1997 a single occupied *Coleura seychellensis* roost was known on Silhouette (La Passe) and two apparently abandoned roosts (Grande Barbe and Pointe Cocos). In addition a high altitude cave was suggested to be occupied by bats in 2004 (BALL 2004), however this has not been substantiated to date. The cave is at approximately 350m a.s.l., in mid-altitude forest. This represents a very different habitat type from the previously recorded roosts and if substantiated would indicate that the species may be more widespread and abundant than previously recognised.

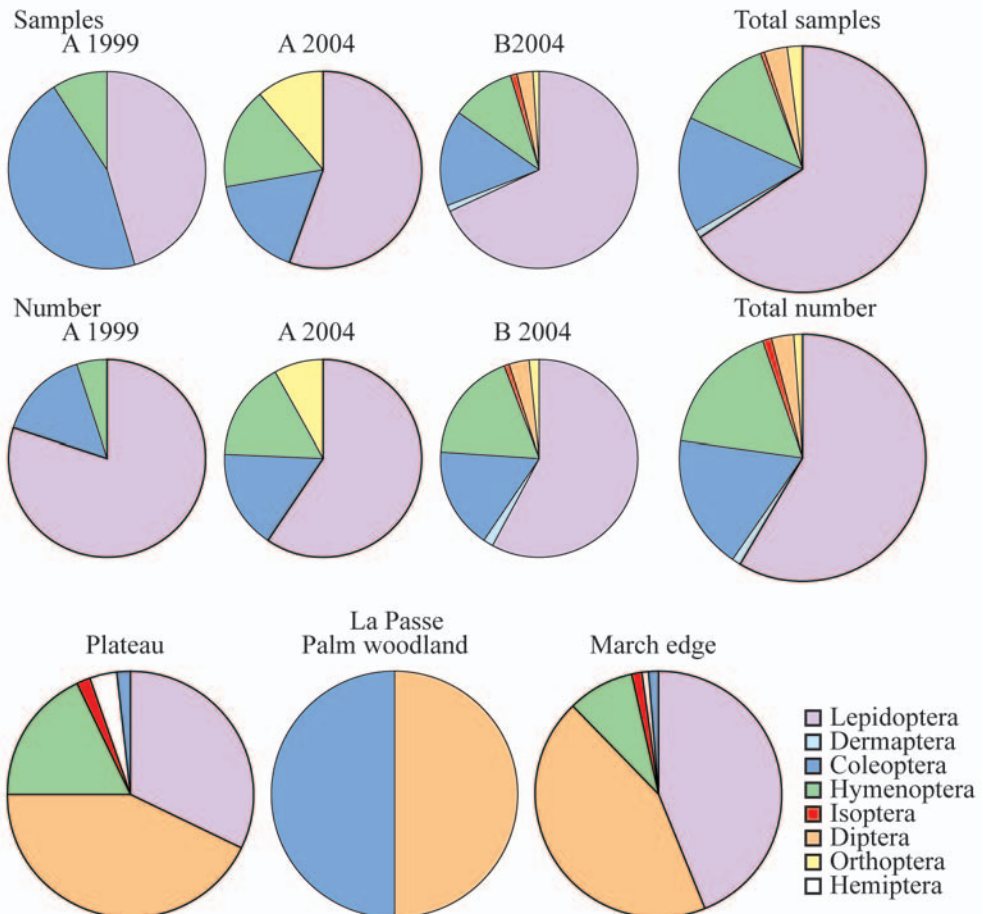


Fig. 6 Numbers of bats recorded in the La Passe roost since 1995, arrows mark the changes in the surrounding environments: 1 - cinnamon cropping near the roost; 2 - decline in use of the copra dryer; 3 - final cessation of use of the copra dryer

The occupancy of the La Passe roosts has been monitored regularly (Fig. 6) since its discovery in 1995. The known population on Silhouette stands at 32 bats. In addition reports indicate the presence of further small roosts on Mahé (observed by the Ministry of Environment) and La Digue (observed by the author in 1996 at dusk at La Reunion). Seychelles sheath-tailed bat faecal samples are dominated by Lepidoptera (61% of faeces, 71% of items), followed by Coleoptera (41% of samples and 20% of items). These patterns were earlier reported by JOUBERT (1995, 2004) who suggested that this was a notable preference as Diptera and Hymenoptera dominated the area's insect fauna. He further suggested that the vocalisations of this species would not be appropriate for prey under 5.5mm in length. A comparison with the nocturnal insect abundance collected in a flight interceptor trap on the same day supports this, with a strong preference for Lepidoptera and Coleoptera and the exclusion of Diptera. However, the large number of faecal samples examined here include a significant proportion of taxa under 5.5mm in length (Fig. 7).

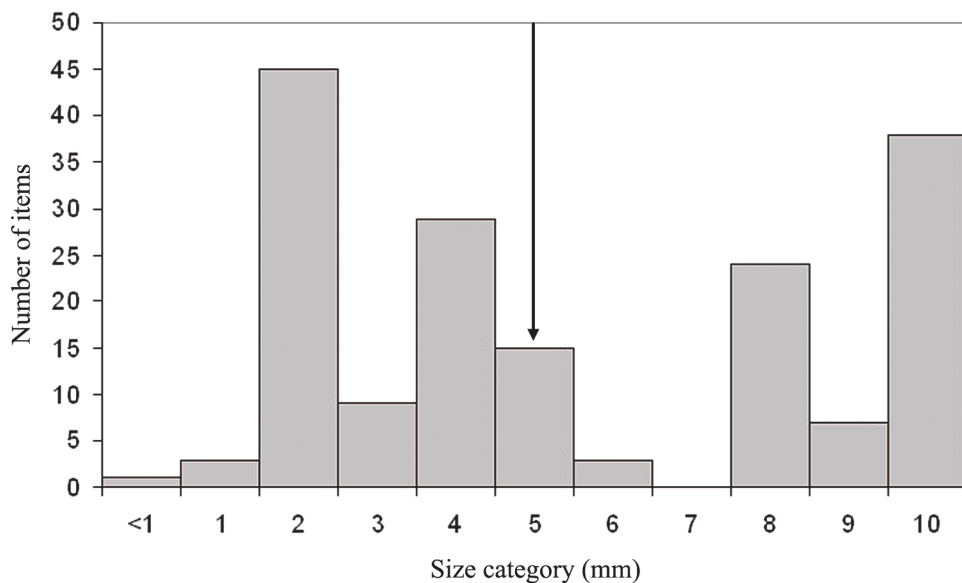


Fig. 7 Size variation in *Coleura seychellensis* dietary items

Of the species identified in the faeces some are associated with low herbaceous vegetation (chrysomelid larva, muscoid flies), some with marsh habitat (Chironomidae) and some with woodland (Curculionidae and *Zarceus fallaciosus*). Some species appear to be too small to be directly consumed; the single cynipid wasp may have been ingested accidentally during capture of another insect and the *Monomorium floricola* may have been present on another food item. The presence of the flightless Chrysomelidae larva indicates that gleaning is used as well as aerial capture. These interpretations are all in accordance with a species feeding opportunistically on a wide range of insects, using a variety of feeding methods and a wide range of habitats.

C. seychellensis has been reported to be a high flying bat based on observations of feeding 15m above ground level (6-20m), flying directly with a slight zigzag pattern (NICOLL & SUTTIE 1982). There are observations of lower flight: 3-5m above ground (MELLAMBY *et al.* 1996) and 1.5-2m above ground, flying up and down and veering side to side (MATYOT 1995). These observations and the dietary data indicate that *C. seychellensis* is largely an opportunistic species, feeding on relatively large insects at a variety of altitudes and habitats depending on where insects concentrations happen to be.

NICOLL & SUTTIE (1982) recorded that the sheath-tailed bats in the Praslin roost were divided into two groups, suggested to be harems with a single male in each in September (1979). The presence of pregnant bats was recorded in November (one in 1977 and 1978, and 2 in 1979). These roosted separately from the main group (both pregnant females in 1979 were together). Young bats were being carried in December (one in 1977 and one in 1979) and April (2 in 1980). Young, free-flying bats were present in the roost in December (one in 1978), January (one in 1978 and one in 1980) and April (2 in 1980). This seems to suggest that a harem system existed in this roost, the date of mating was not determined, but females gave birth in November/December and March/April. An increase in numbers of bats may have followed parturition in June 1979 when the colony was not visited. Thus the data indicate that the females give birth at the start of the north-west monsoon (November/December) and at least occasionally at the end of the monsoon (April). Of the months studied parturition occurred in all three November/Decembers and only 1 of the 3 Aprils (although in the other two years there were small increases in numbers in June/July which could also represent births. 3 of the 4 observed pregnancies resulted in free-flying juveniles. It may be unlikely that the same females gave birth in November/December 1979 and March/April 1980. This would suggest that at least 5 of the 9 bats in the roost in early 1980 were female, as at least two of the bats in October 1979 were male the sex ratio can be estimated to have been between 2:7 and 4:5 (male:female). In the La Passe roost on Silhouette mating has been observed in May (JOUBERT 1996). NICOLL & SUTTIE's (1982) observations of the harem system were limited to three visits, when the bats were in two groups of 4 (with one adult male in each group) (September-October 1979), in three groups of 9, 2 and 1 (June 1980), and in two groups of indeterminate size (July 1980). At other times they were scattered with no clear structuring. The June 1980 observation is also unclear as only one true group existed, with the other three bats being scattered. The harem system therefore cannot be demonstrated unequivocally by these data, similarly observations of the Silhouette roost suggest some social structuring although so far a harem structure has not been definitely identified (BURGESS & LEE 2004).

The available population data on the Seychelles bats does not permit any analysis of population trends. Differences in total population estimates for the Seychelles fruit bat since 1977-9 reflect differences in survey effort and coverage, this obscures any underlying trends. It is notable that several islands that were reported not to have bats present despite historical records have recently been confirmed as supporting roosts. This may suggest that many of the small islands are not inhabited permanently. This is supported by observations that Round island (Praslin) is mainly used during December-January by females with juveniles (R. BRESSON *pers. comm.*).

The fruit bat is of great ecological significance as a major dispersal agent for some of the endemic forest trees (RACEY & NICOLL 1984). There is a need to quantify this dis-

persal role for the rare endemics and also for some of the invasive alien trees. Ecological data are also needed to determine whether current levels of exploitation for human consumption are sustainable. There are no published reports of movement between populations but unpublished data demonstrate regular movements from Praslin to Aride, Cousin and Cousine. Unpublished data also indicate that bats move from Fregate to these islands. The level of movement between Mahé and Silhouette islands are not known. There is a need to determine whether any of the islands operate as separate populations. This has a bearing on exploitation levels as some populations may act as reservoirs, masking over-exploitation on other islands. Basic biological data are currently lacking, impeding such assessments.

Data on the sheath-tailed bat are similarly limited. Location of further roosts on Mahé, Praslin and La Digue are urgent priorities. Ecological data on reproduction and feeding behaviour are also required before any understanding of their status and the significance of the suspected historical declines can be achieved.

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A new taxonomically isolated species of the genus *Phelsuma* GRAY, 1825 from the Ampasindava peninsula, Madagascar

ACHIM LERNER

Beckingsweg 64, 46325 Borken, Germany
[achim.lerner@siemens.com]

Abstract.— A new isolated species, *Phelsuma vanheygeni* sp. nov. is been described from the Ampasindava peninsula, Madagascar. This is the third species with a taxonomically isolated status that has been discovered in the Sambirano domain since 1987. *Phelsuma vanheygeni* sp. nov. reaches an overall maximum length of only 80 mm. Its dorsal coloration including head and tail is vivid green bordered by a yellowish lateral line. The ventral coloration is dirty white. This new species shares its habitat, patches of bamboo forests, with *Phelsuma madagascariensis grandis*, *P. klemmeri* and *P. seippi*.

Keywords.— *Phelsuma vanheygeni*, Reptilia: Squamata: Gekkonidae, Ampasindava peninsula, Sambirano domain

INTRODUCTION

In recent years two taxonomically isolated species within the genus *Phelsuma*, *Phelsuma seippi* (MEIER 1987) and *Phelsuma klemmeri* (SEIPP 1991), were described from the Sambirano domain in north western Madagascar. This paper describes a third independent and isolated species from this climatologically interesting region. This new form shares its habitat, the bamboo forests of the Ampasindava peninsula, with the two previously mentioned species and with *P. madagascariensis grandis*. During our herpetological survey in June 2004, my colleague EMMANUEL VAN HEYGEN and I were able to collect and photograph several animals. Two euthanized specimen were deposited in the herpetological collection of the Royal Museum for Central Africa in Tervuren, Belgium.

MATERIALS AND METHODS

The survey methods and details of the associated herpetofauna are described by VAN HEYGEN (2004). Specimen used in the description are deposited in the herpetological collection of the Royal Museum for Central Africa (RMCA) in Tervuren, Belgium. Scales and preanofemoral pores were examined using a LOMO SF-100 Stereo Microscope. Morphometrics were measured to the nearest 1 mm.

RESULTS

Phelsuma vanheygeni sp. nov.

Fig. 1-6

Holotype

RMCA 2004-34-R-1; mature male, collected June 28th 2004, near the village of Kongony, S 13° 39' 45.7", E 48°04'23.7", 50 m elevation, Ampasindava peninsula, Ambanja Fivondronana, Antsiranana Province, Madagascar, deposited by E. VAN HEYGEN

Paratypes

RMCA 2004-34-R-2; unsexable juvenile, born in captivity, deposited by E. VAN HEYGEN and six life specimen, three adult males and three adult females, S 13° 39' 45.7 ", E 48°04'23.7", 50 m elevation, Ampasindava peninsula, Ambanja Fivondronana, Antsiranana Province, Madagascar, will be deposited in the herpetological collection of the RMCA (by LERNER, A. & E. VAN HEYGEN).



Fig. 1 ♂ *Phelsuma vanheygeni* sp. nov. (life paratype)

All photographs by E. VAN HEYGEN



Fig. 2 ♀ *Phelsuma vanheygeni* sp. nov. (life paratype)

Diagnosis

A small, somewhat slender *Phelsuma* GRAY 1825 with a total length of 75-80 mm (snout-vent length 31-35 mm), head, body and tail are rather flattened. In life, the dorsal coloration, including the head, neck, limbs and tail, is vivid green. Some small red dots irregularly positioned on the lower back and upper tail, usually slightly bigger red dots in males. The green dorsal coloration is bordered by a yellowish stripe, beginning at the rostral scale, over the supralabialia, under the ear opening, widening at the axilla, towards the groin. The ventral coloration is dirty white, the subcaudal scales have at the tips a brown to black pigmentation (Fig. 4). Ventral and subcaudal scales are smooth (not keeled).

Description of the Holotype

All scales are smooth, slightly enlarged scales from the rostral to the eyes and on the tale, the dorsal and dorsolateral scales are small and homogenous (part of the dorsal skin missing, shed while captured). Cleft in the upper part of the rostral, nostril positioned above the suture between the rostral and the first supralabial, the centre of the nostril however is positioned above the first supralabial of the 9/8 supralabials. The nostril is surrounded by 4/3 nasalia with a strongly enlarged prenasal, adjoining over 50% of the nostril. The mental is followed by 7/7 infralabialia, the 3 first infralabialia are larger then the subsequent. The triangular postmental scale is followed by each 3 sublabialia. Four enlarged gular scales contain 22 smaller gular scales between the postmental and the sublabialia. 12/14 Preanofemoral pores, subcaudalia enlarged, one strongly enlarged scale,

three times as wide as long, alternates with two normal enlarged scales, twice as wide as long. The Subcaudalia are in a strait row, smooth and imbricate.

Coloration after three months in preservative yellowish green. The yellow lateral stripes bordering the dorsal and ventral coloration are still very well visible. Dark pigment in subcaudalia still present.

Table 1 Morphometric parameters of RMCA 2004-34-R-1 (Holotype)

Character	Measurement to the nearest mm
Total length	75
Snout—Vent length (tip—cloaca)	31
Tail length (cloaca—tip)	44
Head length (tip to ear opening)	9
Snout length (tip to eye opening)	5
Internarial	2
Nostril—Orbit	4
Orbit—Ear opening	3
Orbit—Orbit	6

Coloration in life

The dorsal, dorsolateral, head, tail and limbs coloration is vivid green, bordered by a yellowish lateral stripe forming an abrupt transition between dorsal and ventral coloration. The dorsal and ventral skin is iridescent, not seen in other members of the genus. Some red dots are present on the lower back and tail, mostly consisting of a single scale. No further sexual dichromatism. A head pattern is very faintly visible, a lighter band crossing before the orbits. The ventral colour is dirty white while the subcaudal region and the limbs are more translucent, resulting in a white-yellowish colour. The preanofemoral region is deep yellow in males. The limbs show some dark brown dots consisting of a single scale.



Fig. 3 ♂ *Phelsuma vanheygeni* sp. nov. (life paratype), showing five longitudinal rows of red dots on the lower back. The lighter spots are healing skin tissue.



Fig. 4 ♀ *Phelsuma vanheygeni* (life paratype) showing dark brown pigmentation on the original and regenerated part of the tail and ♂ *Phelsuma vanheygeni* (holotype), preanofemoral zone (inset)

Variation

Variation in same sex adults is limited.

Juveniles.— There is a strong ontogenetic variation, hatchlings are gold brown, with a dark lateral stripe from the eye to the groin, four green longitudinal stripes and an irregular head pattern. A green transverse before the orbits is present (VAN HEYGEN 2004).

Sexual dichromatism and dimorphism.— Differences between the sexes are limited to a more intense red lower back pattern, often forming five longitudinal rows (Fig. 3), and the yellow preanofemoral zone (Fig. 4) in males. Regenerated tails are usually lighter green in colour. Morphometric variation is minimal.

Gular scalation.— The holotype has a single postmental while two of the paratypes have a pair of postmentalia. The amount of the enclosed scales also varies.

Etymology

Named after EMMANUEL VAN HEYGEN, who discovered the species in June 2004.

Distribution

Phelsuma vanheygeni is so far only known from the Ampasindava peninsula. It is not unlikely that the species equally occurs in other parts of the Sambirano domain with similar habitats.

Habitat

All specimen of *Phelsuma vanheygeni* were collected on medium sized bamboo (ø 5cm). These bamboo patches were found at the edge of the primary forest, within the forest as well as in secondary vegetation areas. *Phelsuma vanheygeni* shares its habitat with *P. klemmeri*, *P. seippi*, *P. laticauda laticauda* and *P. madagascariensis grandis*.

Remarks

The integument.—The integument is extremely fragile and easily autotomized at the slightest pressure, the subcutaneous tissue is grey. *P. breviceps* is the only other member with this degree of integument fragility. Regenerated integument takes noticeably longer to get its original colour than with other species of the genus (Fig. 3). Integumentary loss is considered to have been evolved in response to predators. RAXWORTHY and NUSSBAUM (1994) suggest colubrid snakes as predators, but at the type locality a black unidentified bird was recorded hunting for bamboo dwellers, rapidly moving its head from one side to the other side of the bamboo stem. Both snakes and birds are possible predators.

Gular scales.— The arrangement of the gular scales of *P. vanheygeni* (Fig. 5), four enlarged scales containing several smaller scales between the postmental and the sublabialia is so far only reported from *P. guttata* (LOVERIDGE 1942) and *P. seippi* (VAN HEYGEN *pers. comm.*).

Iridescence.— The dorsal and part of the ventral skin is very iridescent, slightly changing colour depending on the observation angle (Fig 6).

Reproduction.— *Phelsuma vanheygeni* is an egg gluer, 6 mm eggs were found attached to the inner side of bamboo in pairs (VAN HEYGEN 2004). The eggshell is extremely thin. Egg gluing is found in only 8 of the 24 typical Malagasy species; *P. barbouri*, *P. berghofi*, *P. dubia*, *P. flavigularis*, *P. hielscheri*, *P. malamakibo*, *P. modesta* and *P. pronki*.



Fig. 5 *Phelsuma vanheygeni* sp. nov. (holotype) gular scale arrangement and iridescence.



Fig. 6 ♀ *Phelsuma vanheygeni* sp. nov. (life paratype) showing dorsal iridescence

DISCUSSION

Phelsuma vanheygeni sp. nov. holds a taxonomically isolated position within the genus and a sister species neither can be identified, nor can it be assigned to one of the nine Malagasy species groups suggested by GLAW *et al.* (1999). These groups are constituted on alpha taxonomical grounds, no thorough and complete phylogenetic analyses has been done (NUSSBAUM *et al.* 2000). AUSTIN *et al.* (2004) only investigated the relationships of eight Malagasy taxa, two Seychellois taxa and one Andaman species, with the Mascarene taxa. Out of these non-Mascarene species, only *P. andamanensis* glues its eggs to a surface. Three of the groups suggested by GLAW *et al.* (1999) consist only of egg gluing species, the *P. barbouri*-group, *P. dubia*-group and the *P. modesta*-group. The other Malagasy groups contain none.

Due to the fact that *P. vanheygeni* is an egg gluer, the following groups and their members can be excluded as sister taxa; *P. guttata*-group, *P. madagascariensis*-group, *P. lineata*-group, *P. mutabilis* group, *P. laticauda*-group and *P. klemmeri*-group. The remaining possibilities are the *P. dubia*-group, *P. modesta*-group, *P. barbouri*-group and some non-Malagasy species from the Mascarenes and Andaman Islands. The other non-Malagasy forms from Seychelles and the Comoros are all egg layers and can be excluded.

Phelsuma dubia-group.— The members of this group, *P. berghofi*, *P. dubia* and *P. flavigularis* (GLAW *et al.* 1999), are all egg gluers, have enlarged dorsolateral scales and possess no widened subcaudalia. *Phelsuma vanheygeni* differs from *P. dubia* and its sister taxa by its size, by the scale arrangement on the throat (Fig. 3), by the enlarged subcaudalia and by the homogenous dorsal and dorsolateral scales, consequently *P. vanheygeni* can not be assigned to this group as it is not closely related to its members.

The recently described *P. hielscheri* and *P. malamakibo* show similarities with the members of the *P. dubia*-group (Van Heygen 2004b). Both species possess however keeled ventral scales (ROESLER *et al.* 2000, Nussbaum *et al.* 2000), and thus can not be considered as sister taxa of *P. vanheygeni* whose ventral scalation is smooth.

Phelsuma modesta-group.— *Phelsuma cepediana* should not be considered as a member of this group since its close relationship to all other Mascarene taxa. *P. modesta* is characterised by the position of the nostril, smooth ventral scales, strong ontogenetic variation and sexual dichromatism. The centre of the nostril lies above the suture of the rostral and the first supralabial (MERTENS 1970). The juvenile coloration differs from the adults like in *P. vanheygeni* (VAN HEYGEN 2004a). There is a possible distant relationship with *P. modesta* but *P. vanheygeni* can not be classified as a sister taxon since it differs by its characteristic gular scale arrangement and its alternating enlarged subcaudalia.

Phelsuma barbouri-group.— *P. barbouri* is the only member of this group since *P. pronki* is an egg layer and is classified within the *P. klemmeri*-group (VAN HEYGEN 2004b). The subcaudalia of *P. barbouri* are not enlarged whereas those of *P. vanheygeni* are. Other morphological differences like the chin scalation and habitus do not permit to classify *P. vanheygeni* into this group.

The Mascarene-group.— The living Mascarene species include *P. borbonica*, *P. cepediana*, *P. guentheri*, *P. guimbeaui*, *P. inexpectata*, *P. ornata* and *P. rosagularis*, and form a separate group within the genus (AUSTIN *et al.* 2004). *Phelsuma cepediana*, endemic to Mauritius is reported from a single specimen near Ambanja, Madagascar (RAXWORTHY & NUSSBAUM 1993). Its placement within the *P. modesta*-group (GLAW & VENCES 1994) is questionable. Unfortunately, *P. modesta* was not included in the DNA analysis conducted by AUSTIN *et al.* (2004) as it is suggested that *P. modesta* is closely related to the Mascarene-group. Extended research concerning the relationship between Malagasy and Mascarene species is necessary. The members of the Mascarene-group have to be excluded as sister taxa of *P. vanheygeni* based on the habitus, alternating enlarged subcaudalia versus no enlarged subcaudalia in the Mascarene group, the different gular scale arrangement of *P. vanheygeni* and the geographic location of the Mascarenes. The islands are located 800

km east of eastern Madagascar while the type locality of *P. vanheygeni* lies on the north western side of Madagascar.

Phelsuma andamanensis.— an endemic to the Andaman shows most morphological similarities with *P. vanheygeni*; habitus, vivid green coloration, unkeeled ventralia, subcaudalia strongly enlarged, centre of the nostril above the first supralabial and egg gluing. *P. andamanensis* only differs from *P. vanheygeni* by its habitus, size, head and dorsal patterns and minimal ontogenetic variation (hatchlings are green). There is a possible ancestral relationship between *P. andamanensis* and *P. vanheygeni* but the morphometrics of the head are too diverse, *P. andamanensis*' proportional head length is 1.3 the size of *P. vanheygeni*, to consider it a sister taxon.

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The genus *Phelsuma* GRAY, 1825 on the Ampasindava peninsula, Madagascar

EMMANUEL VAN HEYGEN

Winketkaai 16, 2800 Mechelen, BELGIUM
[emmanuel@vanheygen.com]

Abstract.— Several key locations were researched on the Ampasindava peninsula, north-western Madagascar in June 2004. These locations were chosen for their probability of having remaining patches of primary vegetation. Next to the unexpected records of *Phelsuma quadriocellata*, a species normally occurring on Madagascar's eastern coast, a new species, *P. vanheygeni* (LERNER 2004) was discovered. Known distribution ranges for other species were extended, however their presence on the peninsula was expected. These species are; *P. abbotti*, *P. dubia*, *P. laticauda*, *P. madagascariensis*, *P. klemmeri* and *P. seippi*. The first detailed report on the habitat of *P. klemmeri* is made since the description of the species by SEIPP in 1991.

Keywords.— *Phelsuma*, Ampasindava peninsula, Madagascar

INTRODUCTION

The Ampasindava peninsula is located in north-western Madagascar and is part of the district (fivondronana) of Ambanja, province of Antsiranana. Very few primary vegetation is present, except for a few lower altitude rainforests in the higher regions of the peninsula. The 18.000 inhabitants, composed of fisherman, farmers and herdsmen, live in smaller villages spread over the region, resulting in a high rate of “tavy” or slash-and-burn technique. Large patches of forest are cut and burned to plant crops like rice and coffee. The region is very poor and almost entirely depending on its natural resources, increasing the pressure on the unique ecology. There are several footpaths, not wider than 1 m, connecting the villages and sea accesses.

Due to its isolation, the region has been very poorly researched for its herpetofauna in contrast to Nosy Be, which lies about 20 km north of the peninsula, particularly Lokobé forest, the only remaining primary forest area of significance on the island. As late as 1987 a new distinct species, *P. seippi* (MEIER 1987), was described from the reserve. *P. klemmeri*, also recently described (SEIPP 1991) holds an even more taxonomically isolated position. *P. klemmeri* was so far only known from the type locality, indicated by SEIPP (1991) as the coast of north-western Madagascar. A previous survey in 1994 (E. VAN HEYGEN *unpubl.*) revealed that *P. laticauda laticauda* and *P. madagascariensis grandis* are present in the coastal areas (beaches) of the peninsula.

The peninsula lies within the Sambirano climate belt, like the island of Nosy Be and is climatologically influenced by the Massif of Tsaratanana. The Sambirano domain (WHITE 1983) has a typical microclimate with frequent heavy rain alternating with clear skies. Nosy Be gets an average rainfall of 2030 mm a year on 175 days. The temperatures at higher elevations are mainly moderate, between 15° and 25°C. There is a cool, dry season between June and September and a warmer wet season during the rest of the year.

The Sambirano domain is a centre of endemism and a biogeographical transition zone between the species compositions of plants and animals, of the western deciduous forests and eastern rainforests (GOODMAN *et al.* 2003). Relatively little remains of the lowland forest between sea level and about 800 m on the mainland. The highest peak on

the Ampasindava peninsula is 730 m, situated in the central part and is still covered by a relatively large lowland forest. The other primary forest patches are highly fragmented and confined to the higher elevation areas. Some *Phelsuma* species seem to benefit from deforestation and are more abundant in open or cultivated areas than in their natural habitat (GLAW & VENCES 1994), but others like *P. seippi* are only found in or on the edge of primary forests. The Ampasindava peninsula has a high degree of secondary mature vegetation which also can be considered as beneficial for many species of *Phelsuma*, since they seem to be more adaptive than other reptile genera or their predators.



Fig.1 Map of the Ampasindava peninsula and part of the Sambirano region indicating the primary forest zones

METHODS

Prior to the survey, maps and satellite images were compared to locate the remaining patches of primary vegetation and mature secondary forests on the Ampasindava peninsula. Detailed maps of the region were composed, including rivers, footpaths, equal altitudes and other topographic features. A total 5 different survey areas were selected for their isolation, vegetation type and altitude spread over the peninsula.

When a survey area was reached, the different vegetation types were determined and the localities selected. Endemic palms, *Cocos nucifera*, *Ravenala madagascariensis* and bamboo patches were the main focus next to the primary forests. These localities were surveyed for several days, during different hours of the day for possible *Phelsuma* populations.

RESULTS

The different sites and species are individually described below. Exact and accurate locations are not given due to respect for R. SEIPP's decision to not reveal the type locality for *P. klemmeri* for conservation purposes. It has to be mentioned however that neither this species is as critically endangered as previously suggested, nor is *P. seippi* and *P. vanheygeni*.

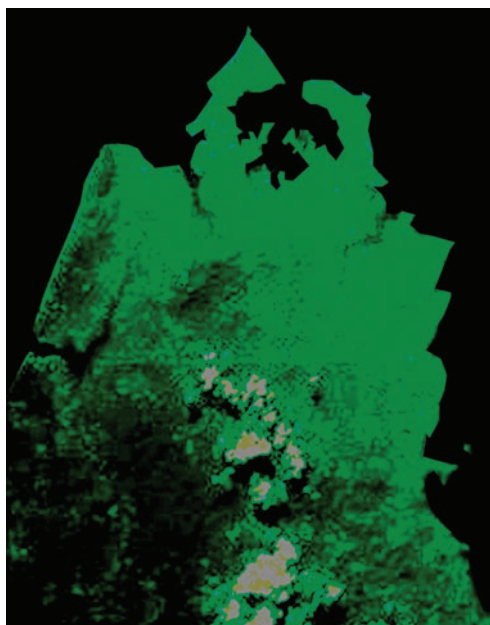


Fig.2: Satellite image of the peninsula, clearly showing the higher density vegetation areas

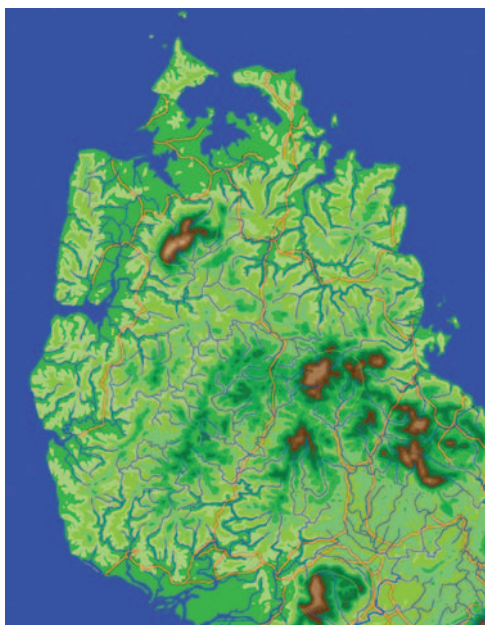


Fig.3: Sample of one of the composed maps, indicating the higher altitudes

Site 1

The first area surveyed is located along the western coast of the peninsula ranging from 0 to 200m altitude. It concerns a relatively long patch of primary forest on a mountain ridge along the coastline. The long beaches are separated from the inland by long rows of *C. nucifera* with underlying low scrub and grasses. The coconut palms are inhabited mainly by *Phelsuma laticauda laticauda*. Surprisingly, *P. dubia* is rather rare in this region and only a few isolated animals were found. The lower regions more inland, up to 50 m, are covered by secondary vegetation and extensive grasslands for Zebu grazing near the few villages along the coast. A few immense bamboo patches were examined near a small river; these were inhabited by *P. laticauda laticauda* and *P. madagascariensis grandis*. In the mature secondary vegetation on trees up to 5 m *P. quadriocellata parva* was found, basking on a ø 4cm branch. *P. quadriocellata parva* was so far only known from Madagascar's eastern coast. In a coffee plantation nearby many juveniles of *P. q. parva* were sighted, indicating it is certainly an established population. Considering the remoteness of the area and the little economic activity, it is very unlikely that this is a case of anthropogenic dispersal. Within the primary forest itself very few *Phelsuma* were found, except for the occasional *P. abbotti chekei* on the larger deciduous trees.



Fig.4 Bamboo forests at site 2

Site 2

This site is situated at higher elevations at the edge and in the primary rainforest on a major mountain slope. The lower slopes are all cleared, mainly for rice and coffee plantations. In the forest are small patches of medium sized bamboo (ø 5 cm), confined by larger deciduous trees and lush and thick vegetation. There where the forest has been cleared by “tavy”, all vegetation has been destroyed, except for the bamboo roots, which lie deep enough under ground to survive the flames. Large bamboo forests are formed (Fig. 4) there since the competition for light and space is non existent, especially not at the growing rate of this bamboo. In bamboo patches within the thick forest, as well as in the secondary bamboo forests, *Phelsuma klemmeri*, *Phelsuma madagascariensis grandis*, *Phelsuma seippi* and the new species *Phelsuma vanheygeni* was found. *Phelsuma abbotti chekei* was not present, although it is mentioned by SEIPP (1991) that *Phelsuma klemmeri* shares its habitat with this species in the type locality. Only one *Phelsuma quadriocellata parva* was found at the edge of one of the bamboo forests and does not seem to be common at this site. The presence of *Phelsuma klemmeri*, *Phelsuma seippi* and *Phelsuma vanheygeni* in the secondary bamboo forests indicates that these species are less vulnerable then suggested earlier. Before their habitat was confined in fragmented bamboo “islands” within the primary forest, but the destructive slash-and-burn technique of the Malagasy farmers gave at least these species new opportunities because new bamboo forests arose in previously cleared areas.

Site 3

Site 3 was chosen for its interesting setting; the primary forest remains lie isolated within a valley, completely surrounded by lower mountains of max. 300 m altitude. This site was only briefly examined during the day and only *P. abbotti chekei* and *P. madagas-*

cariensis grandis was found on the larger deciduous trees and *P. laticauda laticauda* on *Cocos nucifera* and *Ravenala madagascariensis*. A nightly survey of the area exposed a large specimen (300 mm) of *Uroplates henkeli* with orange coloured eyes. Animals found on Nosy Be are noticeably smaller, around 250 mm, and have less conspicuous eye patterns (GLAW & VENCES, 2004).



Fig. 5: *Uroplates henkeli* with unusual eye pattern and colour

Site 4

This site had the highest human population density resulting in a limited amount of pristine forest, however bamboo forest were abundant as expected. The terrain was relatively flat with minor hills up to 150 m, covered with very dense bamboo forests. Within these forests was a relatively high number of *Ravenala madagascariensis* present. On the *Ravenala*, *P. laticauda laticauda* and *P. seippi* was found in high numbers. The bamboo itself was inhabited by *P. seippi* as well and by *P. vanheygeni*. The latter was found only on the medium sized bamboo, never on any other type of vegetation. Extensive searches for *P. klemmeri* were unrewarding, although it seemed to be the ideal habitat. An unknown, rather small species of *Lygodactylus* was also spotted on the bamboo to which it seemed very well adapted. Down at the river, a mangrove patch was inspected and a very blue form of *P. abbotti chekei* (fig. 10) was found on one of the bigger mangrove trees. One *P. dubia*, several *P. laticauda laticauda* and *P. madagascariensis grandis* occupied the palm trees around the villages.

Site 5

This site was located within a pristine forest area at higher altitudes (400 m). Within this forest a high number of endemic palms (*Dypsis sp.*) could be found including several bamboo and *Ravenala* patches. The palms were only populated by *P. quadriocel-*



Fig. 6 Bamboo forest mixed with *Ravenala madagascariensis* at site 4

lata parva while the other two types of vegetation were inhabited by mainly *P. seippi*. On some of the mature deciduous trees *P. abbotti chekei* and *P. madagascariensis grandis* was found. On one of the mountain slopes a exceedingly large bamboo forest was surveyed. The searches for *P. klemmeri* and *P. vanheygeni* were rewarded and several animals were carefully observed. Within the same habitat *P. madagascariensis grandis* and *P. seippi* were found. The unknown *Lygodactylus* sp., as found at site 4, was also present.



Fig. 7 *Lygodactylus* sp. recorded at site 4 & 5

Climate

This survey was carried out in June-July, within the typical dry season for the Sambirano domain. There was very little rain in this period, and the relative humidity during the day measured as low as 45-50% at all sites. Even it did not rain for over a week, the relative humidity at night was always around 75%. Towards dawn, it rose even above 90%, generating high amounts of dew, turning everything wet as if it had just rained. This phenomenon was caused by the extreme drop in temperature at night, especially in the early morning were temperatures as low as 16 ° C were recorded at all inland sites. Day-

time temperatures varied between 28 and 32° C. The maximum relative humidity and maximum temperature values are constant all year round (see Fig. 9) while during the dry season, from June till September, the minimum temperatures (night time) drop drastically, up to 50 %.

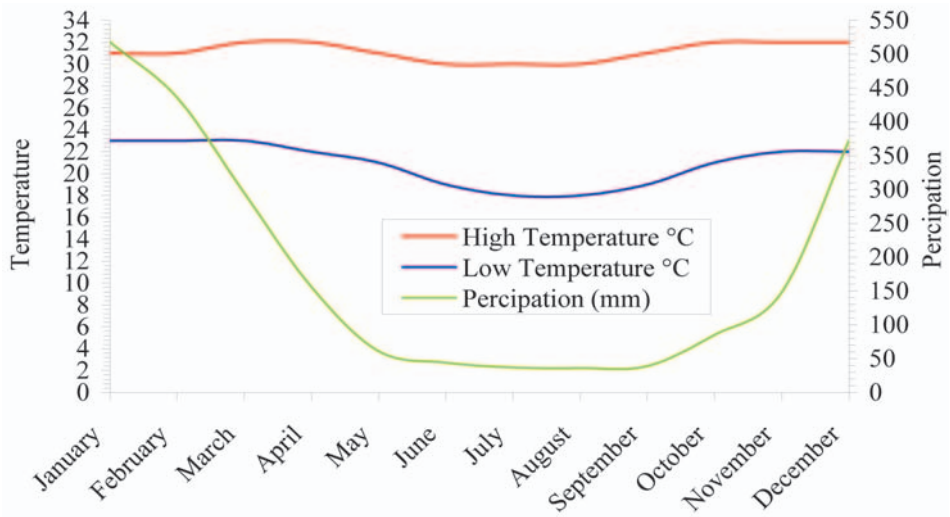


Fig. 8 Average temperature and precipitation values for the Sambirano domain (Alt. 50 m)

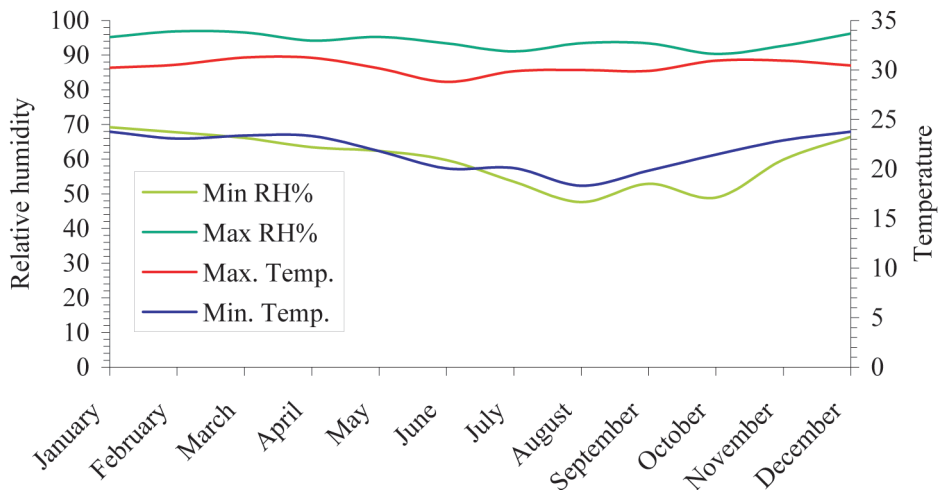


Fig. 9 Relative Humidity, Dew point temperature and Temperature values for 2002

Phelsuma species***Phelsuma abbotti chekei* BÖRNER & MINUTH, 1984**

The coloration of *P. abbotti chekei* varies from one individual to the other. It ranges from blue to green or grey, with marbled flanks and legs. The dorsal pattern consists of red-brown dots and sometimes a median vertebral line is present. It is a medium sized species that reaches lengths up to 145 mm, the females are generally a little smaller and duller in colouration.

Their distribution range is for a Malagasy form quite extensive, it occurs along Madagascar's western coast from Antsiranana in the north, as far south as Antsalova.

Phelsuma abbotti chekei is mainly found on large sun exposed tree trunks outside and at the edge of primary forest patches. On Nosy Be and on the Ampasindava peninsula the species is also found in the coastal mangroves and mangrove trees along swamps and rivers. In western Madagascar, in the seasonal dry forests near Antsalova, the animals are found in the larger deciduous trees. In urban areas like Antsiranana and southern Nosy Be, they can be found on houses and in gardens.

Two further subspecies or known; *Phelsuma abbotti abbotti* (STEJNEGER, 1893) from the Aldabra Atoll, Seychelles and *Phelsuma abbotti sumptio* (CHEKE, 1982) from Assumption Island, Seychelles.



Fig. 10 Extremely blue specimen of *P. abbotti chekei* at site 4



Fig. 11 Normal form of *P. abbotti chekei*

***Phelsuma dubia* (BOETTGER, 1881)**

Phelsuma dubia is a medium sized day gecko, males can reach a total length of 155 mm; females remain somewhat smaller with 140 mm. These altogether flat, however strongly built animals, possess a variable colouring, which can go from light grey over grey green up to leafy green. The tail can in some males appear bluish. On the back appear usually small spots, only consisting of a few scales, which are brown to reddish-brown. The ventral side is bright, partially dirty white coloured. A distinguishing feature is the blue eye ring and the enlarged dorsolateral scales. There is no substantial sexual dichromatism except that the anal region of the males is yellowish.

Phelsuma dubia has the largest distribution area within the genus. In Madagascar the species occurs along the western coast, more concentrated in the north west. *Phelsuma*



Fig. 12 *Phelsuma dubia* at site 1

dubia is also found on all four Comoro Islands, the south Kenyan coast near Mombassa, along the Tanzanian coast and its offshore islands; Pemba, Zanzibar and Mafia Island. On the Ampasindava *Phelsuma dubia* is not that abundant

This species is extremely flexible, can inhabit a variety of different habitats and is extremely anthropophilic. *Phelsuma dubia* has a strong preference for palm trees, *Cocos nucifera*, for which it competes with *P. laticauda laticauda*. It can also be found on coastal *Ravenala madagascariensis* and banana trees

***Phelsuma laticauda laticauda* (BOETTGER, 1880)**

Phelsuma laticauda laticauda can reach about 130 mm in total. The main coloration is vivid green to yellowish green, with three pear shaped spots on the lower back. The neck region is speckled with fine yellow dots, forming often two parallel lines along the vertebrae. Two red lines are present on the head, one is V-shaped before the eye, the other runs from eye to eye. Sometimes a third line is present behind the eyes. The eye rings are blue. Males sometimes can possess a bluish tail, normally it is yellowish with fine reddish dots.

P. laticauda laticauda is without doubt the most abundant species of the Sambirano Domain. It is mainly found in the humid regions of northern Madagascar. Outside Madagascar it occurs, on two of the Comoro Islands; Anjouan and Mayotte, on the Farquhar atoll in Seychelles and it has been introduced onto the Hawaiian Islands.

Like *P. dubia*, it can be found in a variety of habitats except in denser forest re-



Fig. 13 *Phelsuma laticauda laticauda* at site 5

gions. Palms and banana trees are the preferred vegetation, but they can also be found on *Ravenala madagascariensis*, smaller deciduous trees and often in gardens and on houses. Juvenile *P. laticauda laticauda* was sometimes found on medium sized bamboo, where the adults were also found only on the bigger species of bamboo.

***Phelsuma madagascariensis grandis* GRAY, 1870**

This is the largest species found on the Ampasindava peninsula and in the Sambirano domain with a total length up to 300 mm. The main coloration is bright green with irregular patterns of red dots on the back. A red line is present from the nostril to the eye, not behind the eye like in the nominate form.

The southern part of the Ampasindava peninsula is the start of the transition zone between *P. madagascariensis grandis* and *P. madagascariensis kochi* as some animals found clearly showed the latter's characteristics; marbled flanks and smaller red spots on the lower back.

The distribution area is similar to *P. laticauda laticauda* and restricted to the humid parts of northern Madagascar. These two species are very abundant in the Sambirano domain and the Ampasindava peninsula.

P. madagascariensis grandis is found on a wide variety of vegetation, also within the primary forest regions. Here it is found on *Ravenala madagascariensis*, bamboo and the larger deciduous trees. In the secondary vegetation areas the species can be found on



Fig. 14 *Phelsuma madagascariensis grandis* at site 2 on medium sized bamboo



Fig. 15 *Phelsuma madagascariensis grandis* (?) showing strong characteristics of *P. madagascariensis kochi*

the larger trees, *Cocos nucifera*, *Ravenala madagascariensis* and in the bamboo forests together with *P. klemmeri*, *P. seippi* and *P. vanheygeni*. The species is also common in gardens, on houses and in cultivated areas.

No aggression was noticed towards the other smaller species of the genus even not when they share the same tree. On one occasion a *Ravenala madagascariensis* contained three species, *P. laticauda laticauda*, *P. seippi* and *P. madagascariensis grandis*.

***Phelsuma klemmeri* SEIPP, 1991**

Without doubt the most conspicuous of all species is *Phelsuma klemmeri*. The dorsal coloration is brown to turquoise with turquoise dorsilateral bands. A black lateral line runs from the eyes towards the hind legs and is interrupted at the ear openings. Before and after the ear *P. klemmeri* has one or more larger turquoise tubercle scales. This unique feature is only found this explicit in two other species of the genus; *P. nigistriata*, a bamboo dwelling endemic to Mayotte and *P. pronki*, a recently discovered arboreal species of central Madagascar. The head and neck are yellow, the ventral coloration is whitish while the region of the femoral pores is yellow in males. *P. klemmeri* has a very flat appearance and the scales are extremely small and smooth.

P. klemmeri was so far only known from the type locality, indicated by SEIPP (1991) as the coast of northern Madagascar. The species is widespread on the Ampasina-dava peninsula and is not as endangered as previously suggested due to the fact that its habitat is actually extended by human action as described earlier in the "Site 2" section.

This gecko could only be found on medium sized bamboo. When disturbed they immediately retrieve in their hiding, usually one of the many cracks in older dead bamboo which they easily can access due to their flattened bodies. This species is very well adapted to bamboo. Eggs are deposited in these cracks as well. They avoid the hotter parts of the day and can only be seen in the early mornings, in late afternoon or right after a shower when the sun comes through again.



Fig. 16 *Phelsuma klemmeri* close to its hide, a crack in a live bamboo



Fig. 17 *Phelsuma klemmeri* basking on a sun exposed bamboo

Phelsuma quadriocellata parva MEIER, 1983

Phelsuma quadriocellata parva is one of the smallest forms within the genus with a total length of maximum 80 mm. The main coloration is green with an irregular pattern of large red dots on the back. These dots often form a line along the upper vertebrae. A post humeral black spot is present often surrounded by a bluish ring. The eye ring is yellow, the tail is strongly segmented and bluish in males.



Fig. 18 *Phelsuma quadriocellata parva* at site 1

The distribution of *P. quadriocellata parva* was so far restricted to eastern Madagascar around Toamasina. HALLMANN (1997) reports from a population in south-eastern Madagascar in a primary rainforest patch near Befasy. BUDZINSKI (2001) reported a population on Nosy Be, but assumed its presence was due to anthropogenic dispersal since it was only found at one location near a hotel which might have used building materials from eastern Madagascar. The new records of the Ampasindava peninsula indicate a natural occurrence in the region and probably also on the island Nosy Be. This considerably expands the known distribution range of the form and suggests a distribution pattern similar to *P. laticauda laticauda* and *P. madagascariensis grandis*.

On the peninsula *P. quadriocellata parva* was mainly found within the primary forests on high indigenous palms and in the secondary vegetation on smaller deciduous trees and coffee plantations. Populations seem to be very fragmented.

Phelsuma seippi MEIER, 1987

Phelsuma seippi is a small species, males reach up to 117 mm in length (GLAW & VENCES, 1994) whereas females are slightly smaller. The main colour is green with scattered smaller red dots that often form a median line along the vertebrae. A red chevron is present on the head and a darker red stripe runs from the nostril through the eye. The ven-



Fig. 19 Female *Phelsuma seippi*



Fig. 20 Juvenile *Phelsuma seippi*, stalking a bamboo fly

tral coloration is pinkish with two dark chevrons on the throat. Its closest relative is the from the east coast known *Phelsuma guttata*

This gecko was known from its type locality on Nosy Be, Nosy Komba and from Benavony (GLAW & VENCES, 1994) in the Sambirano domain. *Phelsuma seippi* is actually widespread on the Ampasindava peninsula and seems to be more abundant than on Nosy Be.

P. seippi prefers like *P. klemmeri* and *P. vanheygeni* bamboo patches located in the primary forests or secondary bamboo forests and *Ravenala madagascariensis*.



Fig. 21 *Phelsuma vanheygeni* male

***Phelsuma vanheygeni* LERNER, 2004**

This recently discovered species is one of the smallest of the genus. The total length is about 75-80 mm in both sexes. The main coloration is bright green with sometimes tiny red dots near the lower back and tail. The ventral coloration is white, yellow around the femoral pores in males. Characteristic is the yellow lateral line, separating the ventral and the dorsal coloration that is continued on the upper lip.



Fig. 22 *Phelsuma vanheygeni*, clearly showing the yellow lateral line continued on the upper lip



Fig. 23 Female *Phelsuma vanheygeni*

P. vanheygeni is only known from the Ampasindava peninsula where it occupies similar habitats like *P. klemmeri* and *P. seippi*. It was found at three sites out of five during the survey.

The species is confined to the medium sized bamboo (ø 5 cm). They are very well adapted to the bamboo, when disturbed they immediately retreat to smaller bamboo branches that are covered with small leaves. These leaves have the same shape and colour as the animals, making it almost impossible to locate them.

Reproduction.— The eggs of *P. vanheygeni* are glued on the inside of bamboo. The young hatch within 25 days at a daytime temperature of about 27° C. The coloration of the juveniles is gold brown with 4 fine green to dark brown median stripes. The young are extremely small and measure about 25 mm. Regenerated skin of the adults is coloured gold brown like in the juvenile stage.



Fig. 24 Juvenile coloration of *P. vanheygeni*



Fig. 25 Male *Phelsuma vanheygeni*, with a strong red pattern on the lower back

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A study of the bat-fruit syndrome on Mauritius, Indian Ocean

DORTE FRIIS NYHAGEN

Department of Ecology & Genetics
Aarhus University, Ny Munkegade Block 540,
DK-8000 Aarhus C, DENMARK

Abstract.— This study was conducted over a seven month period on Mauritius, Indian Ocean, and concerns the relationship between the endemic fruit bat *Pteropus niger* and 19 food plants upon which it feeds in regard to the bat-fruit syndrome. This is a set of fruit characteristics which suggest an adaptation to fruit bat dispersal noted throughout the world where fruit bats occur. This study has found some evidence of an adherence to the bat-fruit syndrome. Twenty-one percent of the food plants had five of seven characteristics in accordance with the syndrome, 32% had four, 21% had three, 21% had two and 5% of the species had one of the seven bat fruit characteristics. Although the concept of the bat-fruit syndrome is difficult to prove, some of these species may be classified as bat-fruit trees; a species of particular interest was *Labourdonnaisia glauca*. Other food plants had only few traits in accordance with the bat-fruit syndrome, some of which appeared to be adapted to bird dispersal, suggesting a more diffuse relationship between these plants and their seed dispersers and a generalist or opportunistic feeding strategy of *P. niger*.

Keywords.— flying foxes, fruit syndrome, Megachiroptera, *Labourdonnaisia glauca*, *Pteropus niger*,

INTRODUCTION

Following the concept of fruit dispersal syndromes, fruits can be classified according to a set or a syndrome of fruit and seed characteristics (VAN DER PIJL 1982). The fruit of individual plant species may, however, not necessarily possess all characteristics of a particular syndrome (VAN DER PIJL 1982). Previous studies have shown relationships between fruit dispersal syndromes and the attraction of different frugivore taxa in the Old World (KNIGHT 1983, DEBUSSCHE & ISENMANN 1989, KORINE *et al.* 1998) and the New World (JANSON 1983, GORCHOV *et al.* 1995, KALKO *et al.* 1996).

A set of fruit attributes is characteristic to plants being bat-dispersed (VAN DER PIJL 1957, MARSHALL 1983, KORINE *et al.* 1998). These are an easily available, often pendant or cauliflorous position, large fruit size, and large or small seeds (i.e. not of intermediate size), drab or green colours of ripe fruit, strong odours of pulp (e.g. rancid, sour or stale), and juicy pulp (VAN DER PIJL 1957, MARSHALL 1983, KORINE *et al.* 1998). The bat-fruit syndrome appears to be globally valid (VAN DER PIJL 1957). In both the Neo- and the Palaeotropics observations on plants introduced from one continent to the other show that fruit serving as food for bats at one site also attracts bats elsewhere (VAN DER PIJL 1957).

Pteropus niger (KERR, 1792) is the only extant fruit bat species of two, perhaps three species that once inhabited Mauritius (*P. niger*, *P. subniger* and possibly *P. rodricensis*) (CHEKE & DAHL 1981). With an average forearm-length of 152mm it is a species of intermediate size within its genus according to KOOPMAN (1994) (CHEKE & DAHL 1981, NYHAGEN *et al.* 2004). *Pteropus niger* is mainly nocturnal, but occasionally indi-

viduals are seen foraging from early afternoon or even shortly after dawn (NYHAGEN *et al.* 2004). At least 14 major roosts are found in the montane forests of the southeast and southwest of Mauritius and many of these roost sites are found within national park areas (T. BODEY and S. EWING *pers.comm.*, *pers. obs.*). The current status of *P. niger* is unknown, however, the population appears to be healthy due to the protection of the species and absence of any major cyclones in recent years. *Pteropus niger* may play an very important role in regeneration of the Mauritian forest as it disperses seeds and carries pollen of many plant species (NYHAGEN *et al.* 2004).

The diet of *P. niger* is mainly composed of fruit, flower parts and nectar and occasionally leaves. *Pteropus niger* visits at least 22 plant species for food belonging to 19 genera and 13 families (NYHAGEN *et al.* 2004). 32% of these species are endemic to Mauritius, 18% are native and 50% are introduced (SLEUMER & BOSSER 1980, FRIEDMANN 1981, RICHARDSON 1981, MOORE & GUÉHO 1984, BERG & VAN HEUSDEN 1985, SCOTT 1990, WICKENS 1990a, WICKENS 1990b, FRIEDMANN 1997a, FRIEDMANN 1997b, MARAIS 1997). Of the native and endemic plant species, 36% are either vulnerable or rare (WALTER & GILLET 1998).

This study investigates the characteristics of fruit eaten by *Pteropus niger* and addresses the question of whether or not these fruits conform to the bat-fruit syndrome.

MATERIAL AND METHODS

Study area

This study was conducted from October 1999 to April 2000, in The Black River Gorges National Park in the south and south-west of Mauritius. The park covers 65.7km² and includes two lower montane forest areas, Combo and Lower Bel Ombre (150-704m a.s.l.) (SAFFORD 1997) and includes several roosts of *P. niger*. The study was mainly carried out in the lower Bel Ombre forest, but includes observations from Combo forest and Black River Village, situated on the south-western coastline.

Description of fruits

Fruit consumed by *P. niger* was characterised according to its accessibility, size, seed size, colour, odour, flavour and water content. For each characteristic its particular state was scored as either “in accordance” or “not in accordance” with the bat fruit syndrome.

By observing bats landing in and crawling around in trees and noting how easily fruits were retrieved, plant species were grouped in accordance to the accessibility of their fruits. Trees, in which no bats were observed, were categorised on the basis of the position of their fruit.

Size of fruit were classified as small (<10mm), medium (30≥10mm) or large (>30mm) and seeds were categorised as either small (<5mm), medium (5-25mm), or large (>25mm) (length of longest side). Unfortunately, no size categories have been specified in previous studies of the bat-fruit syndrome. In this study, the selection of fruit categories was agreed upon by three fieldworkers and the author as to which fruit sizes were regarded as small, medium and large. The categorisation of seed sizes was based upon the fact that large Australian pteropodids have an oesophageal lumen distendable to 4-5mm, through which passage of smaller seeds is possible (RICHARDS 1990). Previous surveys suggested that seeds longer than 25mm were too large to be included in ejecta of *P. niger*

(pellets of fruit pulp squeezed dry of juice between the bat's tongue and palate).

Often, a fruit possessed more than one state of each character, e.g. a fruit could taste both sweet and bitter, and in this study, for the sake of analytical simplicity, only the most pronounced state was included. Some fruits eaten by bats had multicoloured epicarp when ripe or partially ripe. Here, both colours were included in the data set. Bat-consumed immature fruit was also included and fruit which was consumed as both immature and mature was described as mature.

RESULTS

Bat-consumed fruit from 19 different species (of which 12 were native or endemic) was analysed. The most common fruit characteristics were as follows; easily accessible fruit (95%), medium size fruit (47%), medium size seed (68%), vivid colours (53%), sweet smell (58%), sweet odour (74%), and not juicy, i.e. low water content (58%) (Table 1).

Table 1 Presence of characteristics in accordance or not in accordance with the bat-fruit syndrome in 19 food plants of *Pteropus niger*.

	"In accordance"		"Not in accordance"	
Position of fruit	Easily accessible	95%	Not easily accessible	5%
Size of fruit	Large	42%	Medium (47%) or small (11%)	58%
Size of seed	Large (21%) or small (11%)	32%	Medium	68%
Colour of epicarp	Drab	47%	Vivid	53%
Odour	Musty, sour or rancid	11%	Other	89%
Flavour	Sweet or sour	79%	Other	21%
Consistency of pulp	Juicy	42%	Not juicy	58%

Only two the seven categories (flavour and accessibility) had more species with characteristics in accordance with the bat-fruit syndrome. Five percent of the species had only one of seven characteristics in accordance with the bat fruit syndrome. 21% had two, 21% had three, 32% had four, 21% had five and none had six or all of the seven bat fruit characteristics. The species with five characteristics in accordance with the bat fruit syndrome were *Artocarpus heterophyllus* (Moraceae), *Diospyros tessellaria* (Ebenaceae), *Mangifera indica* (Anacardiaceae) and *Mimusops petiolaris* (Sapotaceae) (Table 2). The fruits of *M. indica* and *A. heterophyllus* are pendant and cauliflorous, respectively. *Diospyros tessellaria* and *M. petiolaris* are endemic to Mauritius, whereas *A. heterophyllus* and *M. indica* are introduced cultivated plants and all four species were popular food plants of *P. niger*.

Table 2 Four of *P. niger*'s food plants with five of seven characteristics in accordance with the bat-fruit syndrome

<i>Artocarpus heterophyllus</i>	Green/brown (drab) colour, musty smell, sweet flavour, cauliflorous position, large fruit
<i>Diospyros tessellaria</i>	Green (drab) colour, sweet flavour, juicy, easily accessible position, large fruit size
<i>Mangifera indica</i>	Sweet flavour, juicy, pendant position, large fruit size, large seed size
<i>Mimusops petiolaris</i>	Green (drab) colour, sweet flavour, easily accessible position, large fruit size, large seed

Labourdonniasia glauca (Sapotaceae), another popular food tree of *P. niger*, possessed four of the seven characteristics typical of bat-fruits. This species has a medium-sized fruit which is dull-green, smells vaguely sour and contains a single medium sized seed. Fruits are placed in the outer canopy on fairly thick twigs, making fruits visible from above and easily accessible. Bats appeared to land and forage in these trees with ease, due to the thick and open branch structure of the tree. The fruiting season of the study population of *L. glauca* started in November, and mature fruits were found until the end of April, providing a source of food for the bats for much of the year. Besides *P. niger* the only other vertebrate foraging on these fruits was the introduced monkey (*Macaca fascicularis*).

Fruit of the species *Protium obtusifolium* (Burseraceae) also had four traits in accordance with the bat-fruit syndrome, although other characteristics contradict this classification. The thick epicarp contained a bitter juice (the taste resembled turpentine) and opened asymmetrically along a crevice. This shell was unattached to the sweet, pink pulp, which was well-fastened to the seed. Bats were not capable of breaking up this fruit and they chewed on the bitter epicarp without being able to separate it from the pulp. Parrots, however, neatly handled these fruits using their beak, first to open the fruit and discard the epicarp and subsequently the pulp was scraped off the seed and ingested. These observations were made on introduced ring-necked (*Psittacula krameri*) and captive echo-parakeets (*P. eques*), the later being endemic to Mauritius and once inhabited the areas where *P. obtusifolium* is found.

Several other food plants of *P. niger* also seemed to be more adapted to bird dispersal according to the “bird syndrome”. This syndrome includes fruits that are small (JANSON 1983, GAUTIER-HION *et al.* 1985, GORCHOV *et al.* 1995, KALKO *et al.* 1996, KORINE *et al.* 1998), taste sweet (GAUTIER-HION *et al.* 1985), are green when immature (VAN DER PIJL 1982) and have signalling colours such as black, purple or red when ripe (VAN DER PIJL 1982, JANSON 1983, GAUTIER-HION *et al.* 1985, GORCHOV *et al.* 1995, KALKO *et al.* 1996). Fruits of the three species; *Sideroxylon cinereum* (Sapotaceae), *Grangeria borbonica* (Chrysobalanaceae) and *Warneckea trinervis* (Melastomataceae) are small, have green immature fruits, which turn red, purple or black when ripening and therefore possess several characteristics typical of bird-fruits.

DISCUSSION

The bat-fruit syndrome is based around seven plant characteristics which on their own seem quite vague, e.g. juicy or easily accessible fruits are common traits amongst fruits in general. The most common combination of fruit characteristics amongst the 19 fruit species was sweet flavour, high water content and an exposed position. However, these characteristics are also found among fruits eaten by other animal taxa such as other mammals and birds (VAN DER PIJL 1982, GAUTIER-HION *et al.* 1985, KALKO *et al.* 1996).

The concept of fruit syndromes is questioned by several authors (HOWE 1980, HEITHAUS 1982, HOWE and SMALLWOOD 1982, HERRERA 1985, HERRERA 1987, WILLSON *et al.* 1989). WILLSON (1989) suggests that fruit colour may attract fruit or seed destroyers as well as dispersers and colours may serve alternative functions such as affecting the thermal regime of developing fruits. Phylogenetic and historical constraints on the evolution of fruit colours may also be an important factor (HERRERA 1985, WILLSON *et al.* 1989).

Adjustments between plants and their dispersers may be coarse or diffuse, rather than finely tuned (HOWE 1980, HERRERA & JORDANO 1981, HEITHAUS 1982, HOWE & SMALLWOOD 1982). HERRERA (1985) discusses the co-evolution of plants with fleshy fruits and their vertebrate dispersers and some of the ecological and evolutionary constraints, which may be important to any occurrence of plant-animal evolution. He states that traits in plants and their dispersers resulting in successful seed dispersal are a necessary, but not a sufficient condition to infer co-evolution (HERRERA 1985). For example, introduced plants or birds may interact with native counterparts and result in successful seed dispersal (HERRERA 1985).

The evolution of species-specific systems may be affected several factors. First, it is harmful to plants to restrict access to their fruits beyond a certain threshold (JANSON 1983, HERRERA 1985), as plants thereby become vulnerable to loss of dispersers. This may explain the presence of coarse or diffusely evolved plant-animal dispersal systems ("guild-syndromes"), where plants have evolved fruit traits which attract a wide variety of animal taxa, which may again consume a wide variety of fruit types. Secondly, high environmental variance (as opposed to genetic variance) and selective pressures by non-dispersers may combine to produce a low uniform selection from dispersers on plants (HERRERA 1985). Such factors may have played a part in the evolution of Mauritian plants and their plant-disperser species. Thus, most plants analysed in this study may have fruit characteristics suitable for attracting a variety of dispersers including fruit bats and confirm more to a kind of "guild syndrome".

Four species had five of seven characteristics consistent with the bat-fruit syndrome (*Artocarpus heterophyllus*, *Diospyros tessellaria*, *Mangifera indica* and *Mimusops petiolaris*). These species may be classified as "bat-fruit trees", and were certainly popular food plants of the bats.

In the description of the syndrome, no measurements of fruit or seed sizes were specified and the classification into size groups was made subjectively. Had fruit and seed sizes been set differently, a different picture would have emerged, i.e. had seeds larger than 25mm in length been included as "large fruit", three species would have had another trait in accordance with the syndrome.

One of these species is *Labourdonniasia glauca*, an endemic tree to Mauritius with four of the seven bat-fruit characteristics. A curious trait of *L. glauca* is a very high concentration of latex in the fruit pulp (NYHAGEN *et al.* 2004). Compared to fresh latex in fruit, latex in ejecta was firmer and stickier, quite like chewing gum, causing the seed and pulp to stick together. Feeding observations of bats in the wild showed that the duration of processing one *L. glauca* fruit into ejecta was significantly higher compared with e.g. *Diospyros tessellaria*, which has fruits of similar size to *L. glauca*. Four times as many *L. glauca* ejecta contained seeds than those of *D. tessellaria*. The high content of latex in *L. glauca* fruits may prolong the feeding duration and length of time which seeds are attached to the pulp, explaining the high seed load of ejecta which may enhance the dispersal of *L. glauca* seeds. Seeds of *L. glauca* have been observed to be dispersed by *P. niger*, and seeds in ejecta from this species have been found germinating (NYHAGEN *et al.* 2004).

Pteropus niger is the only native vertebrate to feed on *L. glauca* fruits, but it is likely that the extinct fruit bat *P. subniger* or other extinct animals of Mauritius fed on these fruits as well. Based upon fruit characteristics in accordance with the bat-fruit syn-

drome, the high latex contents of the pulp, its popularity and general foraging behaviour of the bats on this species, and the fact that no other native vertebrate feeds on its fruit, *L. glauca* appears to be closely associated with bats for seed dispersal and may be an example of a bat tree described by VAN DER PIJL (1957), MARSHALL (1983) and KORINE *et al.* (1998).

The bat-consumed fruit species included in this study showed much variation and may be adapted to dispersal by bats and/or other frugivores. This may indicate that *P. niger* is a fruit generalist or opportunist. Alternatively, this pattern may be explained by convergent evolution of “guild syndromes” among these food plants of *P. niger*.

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Notes & Shorter Contributions

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The bats of Aldabra atoll, Seychelles

A.M. HUTSON

Winkfield, Station Road, Plumpton Green, East Sussex BN7 3BU, UK
hutsonatpavilion.co.uk

INTRODUCTION

Four bat species are recorded from the Aldabra group of islands and all are recorded from Aldabra itself. Two species, *Pteropus aldabrensis* and *Chaerephon pusilla*, are endemic and are included in the IUCN Red List of Threatened Animals. General accounts can be found in HILL (1971), CHEKE & DAHL (1981) and RACEY & NICOLL (1984). This paper updates these earlier works, adding further records and further information that has become available. It is likely that additional information is lodged with the records of the Research Station on the island. No attempt has been made to obtain such

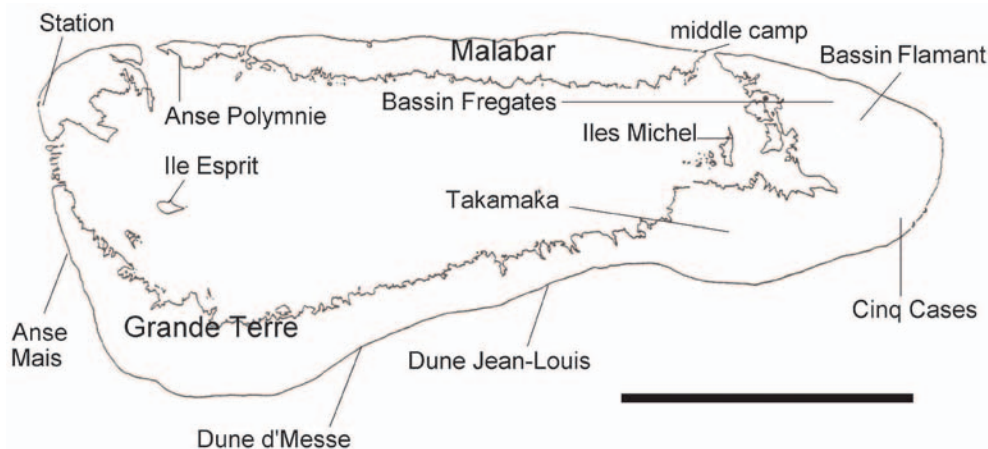


Fig. 1 Localities on Aldabra atoll. Scale bar 10km

data for this paper, but a summary is provided by BRANDIS (2004).

Pteropus aldabrensis TRUE, 1893 (Pteropodidae)

A small-sized flying fox (forearm: 128–141mm), endemic to Aldabra and assessed as Vulnerable in the IUCN Red List of Threatened Animals and in MICKLEBURGH *et al.* (1992). Although described as a separate species, this form was for a long time regarded as a subspecies of *P. seychellensis*, known from the Seychelles, Comoro Islands

and Mafia Island off Tanzania (e.g. HILL 1971). BERGMANS (1990) elevated it to a full species and this has been accepted.

Apart from the original material collected by Abbott in 1893, early records include a skull collected by DR A. VOELTZKOW in 1895 from the house on Aldabra that had been occupied by ABBOTT. FRYER (1911) obtained a further six specimens in 1908, and singles were taken by THIBAUT in 1906, THOMASSET in 1907 and CHARBONNIER in 1954 (BERGMANS, 1990). The species occurs on all main islands of Aldabra Atoll, but in relatively small numbers and no major colony site (camp) has been identified. The largest group located in 1968 was on the small lagoon islet of Iles Michel, where bats were roosting scattered among coconut palms. No full count was made, but the colony was probably well under 100 (A.M.HUTSON, *pers.obs.*). They were also noted roosting among mangroves at Takamaka landing. The only other site where significant numbers were seen was among the coconuts at Settlement (West Island), but these were bats that arrived at night to feed and no roost was identified on this island. It is likely that at that time any major roost would be fairly obvious on an island like Aldabra, but it is possible that the majority of the population was located on Middle Island, which was relatively little explored at that time. FRYER (1911) also noted that, unlike the Seychelles flying fox, this bat does not “form large gatherings in a tree during the daytime”.

Apart from the bats foraging around Settlement (West Island), in early 1968 single bats were noted at Frigate Pool (20 January), Flamingo Pool (21 January), Cinq Cases (27 January), reasonable numbers in the Takamaka area (1-15 February), one crossing from East to West over East Channel to Middle Camp (20 February), several around Dune Jean-Louis (20 March) and one at Dune d’Messe (21 March); all on South Island (A.M. HUTSON, *pers. obs.*)

During a brief visit to Cosmoledo Atoll on 6 March 1968, Jack Frazier thought that he may have seen a fruit bat at dusk on Menai Island (J. FRAZIER, *pers.comm.*).

In the early part of 1968, the present author trapped 14 fruit bats, at Settlement (6M and 2F on 30/31 January), Takamaka Grove (1M on 12 February, 3 M on 15 February), Dune Jean-Louis (2F on 20 March). Many were regarded as juvenile. For the eight at Settlement sex, weight, total length, forearm, pollex length, hind foot, calcar, vibrissae, inner and outer ear length were recorded. Weights were for males 257, 290, 295, 295, 300, 395g (mean: 305g), for females 218 and 228g (mean: 223g); overall mean: 285g. Forearm lengths were for males 135, 135, 137.5, 138, 140, 141mm (mean: 137.8mm), for females 128 and 129mm (mean: 128.5mm); overall mean: 135.4mm. Of adult museum specimens measured by BERGMANS (1990), including some of the above individuals, seven males had a range of 133.8 - 140.8mm, two females 131.5 and 136.0mm. Ear lengths (inner notch to tip) of the Settlement animals ranged from 24 - 27.5mm.

Little information on breeding has been published (CHEKE & DAHL 1981). Mating has been observed in March, June, October and November, but females carrying young have only been recorded in December and January.

Food plants identified (FRYER 1911, CHEKE & DAHL 1981, RACEY & NICOLL 1984; ROBERTS & SEABROOK 1989; A.M.HUTSON, *pers. obs.*) include fruits of *Ficus lutea*, *F. rubra* (as *F. avi-avi*) and *F. reflexa*, *Calophyllum inophyllum*, *Terminalia catappa*, *Mystroxydon aethiopicum*, and flowers of *Cocos nucifera* and *Agave sisalana*. Bats have also been recorded eating the foliage of *Avicennia marina*.

ROBERTS & SEABROOK (1989) also record feeding on honeydew produced by in-

festations of the coccoid *Icerya seychellarum* on *Ficus lutea*. In August 1986 at Cinq Cases (South Island), a fruit bat was observed licking the upper side of the leaves of a heavily infested plant. In September 1986, one bat was watched licking the underside of the leaves of a light to moderately infested tree on 3rd September at Anse Badamier (Middle Island) and on 8th September at Anse Malabar (Middle Island) and the upper surface of the leaves of a more heavily infested tree at Anse Malabar on 15th September. This behaviour was observed for up to 45 minutes. Rats (*Rattus rattus*) were observed carrying out similar behaviour.

CHEKE & DAHL (1981) record interactions with birds, such as mobbing by frigate birds, drongo and kestrel, and crows pecking at the feet of bats roosting from coconut leaves.

The absence of any insect ectoparasites on these bats (usually Diptera Nycteribiiidae) was noted by SCOTT (1914) and again by the present author in 1968 (COGAN *et al.* 1971). Indeed, in 1968 only some demodicid-type mites were collected from 16 fruit bats examined. The absence of Nycteribiidae may be related to a practice in the species of not roosting in large dense colonies at sites of long tradition.

The present author considered that it was unlikely that the adult population exceeded 250 in 1968, which would make the species one of the rarest bats in the world and extremely vulnerable to extinction should any significant adverse changes occur to the island.

There is a clear need to get better and up-to-date population estimates and to collect more information on the reproduction and ecological needs of the species. As a UNESCO World Heritage site and a special reserve under the Seychelles National Parks and Nature Conservancy Act, the habitat should be protected, but consideration should be given to giving the species individual legal protection (and the same should apply to *Chaerephon pusilla* – see below).

***Taphozous mauritanus* E. GEOFFROY, 1818 (Family Emballonuridae)**

A middle-sized sheath-tailed bat (forearm: 60-65 mm), widely distributed from Mauritius, through Madagascar and much of sub-Saharan Africa (TAYLOR 2000). It would appear to be widely distributed but rare in Madagascar (BENNETT & RUSS 2001; GARBUTT 1999; PETERSON *et al.* 1995).

Two specimens (both male) were collected from around the settlement on West Island (Ile Picard) on 5th and 17th June 1968 by J.G.FRAZIER and are in the British Museum (BM 69.16-17). No other confirmed records are available. However, ABBOTT (1894) records that, apart from the large fruit bat, he saw two smaller bats (one of which was collected and is discussed under *Chaerephon pusilla*), and FRYER (1911) recorded the species from sight records, but stated that it was scarce. One bat seen in January 1968 over White Cross camp, near Frigate Pool on South Island (Grande Terre) was described as a 'noctule-sized bat' (*Nyctalus noctula*) and may have been this species (A.M. HUTSON, pers.obs.). BETTS (2000) records a large bat (suggested to be *Taphozous mauritanus*) to be regular around the Research Station and Bassin Flamant, with a roost at the station in July/August 1998.

The island would appear to offer suitable habitat for both roosting and foraging. For roosting, the species will occupy any site offering shelter from sun and rain, including dead palm leaves that have collapsed against the trunk of the tree. They will also roost in

quite exposed situations.

A single record for Assumption (SCOTT 1914) is based on specimens collected by Fryer in September 1908. The bats were found clinging to the stem of a big coconut palm (“the only big one on the island”) just below the crown of leaves. Two specimens were collected while others escaped capture.

SCOTT (1914) described a new species of Nycteribiidae, *Nycteribia (Acrocholidia) fryeri*, from 18 specimens collected from Fryer’s bats (and a single specimen from La-buan). FRYER (1911) makes no mention of these bats - or, indeed of any bats for Assumption, Cosmoledo and Astove. In 1917, SCOTT designated *N. fryeri* as the type species of a new genus *Tripselia*, but the species is now regarded as a synonym of *Basilia (Tripselia) blainvillii*, a widespread parasite of *T. mauritanus* (see THEODOR 1967).

It is likely that the species is resident in small numbers on Aldabra; its present status on Assumption is unknown. It is generally a high flying bat (above the canopy and in open areas) and so is less likely to be caught in mist nets, but its echolocation calls would be distinctive (see TAYLOR 2000).

***Triaienops furculus* TROUESSART, 1906 (Hipposideridae)**

A small distinctive leaf-nosed bat (forearm: 42–47 mm) described from Madagascar, where it is distributed around the north-western coastal areas.

FRYER (1911) reports that this species was “not uncommon on Picard near the Settlement”. A specimen was sent to TROUESSART who confirmed the identification. Apart from this record from Ile Picard (West Island, Aldabra), Fryer apparently obtained two specimens from Cosmoledo which are now in the British Museum (BM 13.2.18.1-2). There is an additional specimen in the British Museum (BM 78.185) collected by J.J. WHITELAW, 4th May 1977 from Aldabra, possibly from the Research Station on West Island. The bat weighed 6.5g and was preserved in alcohol. F.A.HARRINGTON (in litt., 25.1.1993) reported seeing a *T. furculus* on Aldabra in 1992, but no further details were forthcoming. There are no other records from the Aldabra group and its status here remains uncertain.

In Madagascar it is essentially a cave bat (often sea caves), often forming large colonies and sometimes mixed with other species. The Aldabra group of islands has no true caves. On Aldabra, there are shallow undercut cliffs which might provide temporary shelter but which would be frequently wave-washed. Inland there are some vertical solution holes, which are at most about 5m deep, and other small hollows which might provide a limited cave-like environment. It is notable that of the four main islands of Aldabra, West Island would seem to offer the least opportunity to a cave bat. At least the largest islands of Cosmoledo Atoll, Wizard and Menai Islands, would appear to be even less suitable with very limited suitable foraging areas and even less cave-like situations (BAYNE *et al.* 1970). The possibility of these being vagrants from Madagascar cannot be ruled out, but this is unlikely to be a migratory species and the coincidence of finding three individuals on the same expedition is curious. These and the more recent records suggest a small resident population.

The species is likely to stay close to or within vegetation when foraging and the echolocation calls, although distinctive (see BENNETT & RUSS 2001), would be difficult to pick up, especially without the use of a broad band detector.

***Chaerephon pusilla* (MILLER 1902) (Molossidae)**

A very small endemic free-tailed bat (forearm 36.5-39 mm). Included in HUTSON *et al.* (2001) as vulnerable (D1+2).

The species is closely related to *C. pumila* (CRETZSCHMAR, 1826), a widespread species of Madagascar and Africa. The original specimens, collected from Aldabra by Abbott in 1893, were identified by True (in ABBOTT 1894) as *C. pumila* and subsequently described as a new species, *Nyctinomus pusilla*, by MILLER (1902). Hill (1971), on the basis of the original and more recently collected specimens, recognised *pusilla* as distinct, but noted that it is 'clearly closely related to *pumila* and may prove conspecific'. It is much smaller and darker than any *pumila* seen by the current author and HILL (op.cit.) notes their 'very much smaller, less massive skulls and smaller teeth'. However, HAYMAN & HILL (1971) considered *pusilla* a synonym of *pumila*. The forthcoming 3rd edition of *Mammalian Species of the World* (SIMMONS, *in press*) treats it as a distinct and endemic species.

The original material of Abbott (ABBOTT 1894) comprised two specimens, including one adult female (MILLER 1902). A male was collected by C.A. WRIGHT on 4 October 1966 from the eastern shore of East Channel (Passe Houareau), South Island (BM66.5573). The present author observed bats presumed to be this species in 1968 at Cinq Cases (singles on 11 January and 27th January), several around Takamaka (8-14th February), Dune Jean-Louis (16-19th March) and Dune d'Messe (21st March); all on South Island. At the same time there were reports of small ('pipistrelle-sized') bats around the Settlement on West Island. Specimens were trapped at Takamaka Grove (1M, 1F on 12th February, 2F on 13th February and 1F on 14th February) and are in the British Museum (BM.68.938-942). Subsequently, single females were caught at Takamaka Grove by R. LOWERY on 6 and 13 June 1968 (BM69.784/5), and a male at Settlement on 7 June by J.G. FRAZIER (BM69.18) (HILL 1971).

SEABROOK & ROBERTS (1986) noted Microchiroptera, probably this species, at Anse Mais (West Island) as seen frequently between March 1985 and February 1986 where the bats were foraging within coconut and casuarina 'parkland'; infrequently around the Research Station (West Island) between May and June 1986 (again in coconut and casuarina 'parkland') and on the beach crest; and individuals at Anse Cedre (South Island) on 14th and 15th October 1986. A single roost, occupied by about 30 individuals of *C. pusilla* was located within 30m of a house in the Settlement (West Island) in holes in a *Casuarina* tree. Two entrances (one 120 x 50mm, the other 100 x 70mm) were at about 6.5m above ground and approximately 300mm apart. The roost was first located in August 1986 and was still occupied when the observers left the island at the end of November 1987. Repeated observations indicated that the bats emerged soon after dusk (19.00 hrs) and returned at dawn. Twelve individuals (10F, 2M) were caught and examined (?in late August).

A single specimen from the Amirante Islands, collected by Capt. K. PERCON and presented by G.E. MASON to the British Museum (Natural History) (BM 28.1.24.4) was regarded by HILL (1971) as *C. pusilla*.

The species is host to an endemic ectoparasitic polychtenid bug, *Hypoctenes hutsoni* MAA 1970.

Bats caught by the current author in 1968 were noted (and photographed) as generally very dark, almost black, with no ventral mid- or lateral bands, and no obvious post-

aural crest in the single male examined.

The weights of four of the five bats trapped by the current author were 6.0g (M), 7.0g (F), 7.0g (F), 7.5g (F) (mean 6.9g). Weights for the twelve individuals examined by SEABROOK AND ROBERTS were 6.3 and 7.4g for two males (mean: 6.9g), and 6.7, 6.7, 6.9, 7.0, 7.1, 7.2, 7.3, 7.3, 7.4, 7.6g for ten females (mean: 7.1g); overall mean: 7.1 g. This is much lighter than weights given for *C. pumila* from elsewhere, e.g. 9–11.5g in Madagascar (BENNETT & RUSS 2001), 10–16g (mean 11g for M, 12g for F, n=118) for southern Africa (TAYLOR 2000).

For the nine specimens collected between 1966 and 1968, HILL (1971) gives a forearm range of 37.4 – 38.6mm (mean: 38.1mm). Forearm lengths for the twelve individuals examined by SEABROOK & ROBERTS were 36.5 and 37.5mm for males (mean: 37.0), and 37.0, 37.5, 38.0 (x5), 38.8 and 39.0mm (mean: 38.1mm); overall mean: 37.9mm. These forearm lengths can be compared with forearm lengths for *pumila* of 38 – 41mm for Madagascar (BENNETT & RUSS 2001) and 35–40 (mean: 37mm for M and F; n=91) for southern Africa (TAYLOR 2000).

The species appears to catch readily in mist-nets, but could also be surveyed for using bat detectors; the echolocation calls are unknown, but assuming them to be similar to those of *C. pumila* (see TAYLOR 2000), they would be readily distinguishable from other recorded species. Its occurrence on the Amirantes needs confirmation.

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A summary of recent bat records from Aldabra atoll

R. VON BRANDIS

c/o Seychelles Islands Foundation,
P.O. Box 853, Victoria, Mahé, SEYCHELLES



Fig. 1. Bats of Aldabra atoll, from top to bottom: *Taphozous mauritanus*, *Triaenops furculus*, *Chaerophon pusilla*, *Pteropus (seychellensis) aldabrensis*. (drawing by J. GERLACH)

References to bats in the records cards kept in the Aldabra Research Station were collated and are summarised below.

Fruit bats

Fruit bats have been observed on virtually every corner of the atoll where there is either suitable feeding or suitable roosting to be had (various authors 1970-2004). They are more commonly encountered in mangrove stands where they can both feed and roost (various authors 1970-2004). They are also often observed in taller trees such as Casuarinas and coconut palms (various authors 1970-2004). Large groups of fruit bats (up to 40) have been sighted roosting in Casuarina trees on Ile Esprit (S. WOODSELL 1974, A.S. GARDNER 1981). At the Takamaka grove on Grande Terre, 48 bats were seen roosting in 2000 (M. BETTS). On Ile Michel groups of up to 50 were noted in 1974 (S. WOODSELL). Even larger groups (100+) have been observed in the Casuarina trees on the eastern end of Malabar Island (S. PIERCE 1995).

Fruit bats are regularly observed flying across channels to visit other islands (various, 1970-2004). Occasionally they carry their young with them under their bellies (R. HNATIUK 1975). Various accounts (sometimes very graphic) of mating have been recorded (various observers 1970-2004). Often the prominent penis and the grooming of it after copulation by the male have been emphasised.

Fruit bats have been seen feeding on a variety of plants: fruits of *Terminalia catappa* (I.R.S 1975), *Mystroxydon aethiopicum* (R. HNATIUK 1975) and *Ficus rubra* (as *F. avi-avi*; S. HNATIUK 1973); leaves of *Avicennia marina* (R. HNATIUK 1974; and flowers of *Agave sisalana* (unknown observer 1973) and *Cocos nucifera* (R. HNATIUK 1974). Fruit bats have been seen eating coconut from nuts that they themselves had opened by gnawing at them with their teeth (Local staff members 1974 -2004). Once, a fruit bat was found with its head lodged firmly in a coconut at the top of the tree. The bat was released from the nut upon which it climbed back up the coconut in order to get some altitude to fly off (P. ROGERS & U. SAMEDI 2004)

Fruit bats are often mobbed by birds: pied crows (*Corvus albus*) have been noted to peck at roosting bats and generally harassing them (R. HNATIUK 1973), the Aldabra drongo (*Dicrurus aldabranus*) (unknown observer 1974), frigate birds (*Fregatta* spp.) (S. HNATIUK 1974, WOODSELL 1974) and the Madagascar kestrel (*Falco madagascariensis*) (S. HNATIUK 1973) has also been observed mobbing the bats

Table 1 Data on microchiropteran bats captured on Aldabra

	Bat 1	Bat 2
Place of Capture	Station	Station
Date of capture	1974	1977
Recorder	J. Wilson	J. Whitelaw
Body length	79mm	66mm
Tail length	28.6mm	18mm
hind foot	6.8mm	8.5mm
Ear length	12mm	14mm
Forearm	39.2mm	45mm
Fresh weight	5.7g	6.5g
Sex	male	male

Other bats

A small species of insectivorous bat has been sighted at the following places by various observers between 1970–2004 at Anse Mais, Middle camp, Station, Cinq Cases hut, Anse Polymnie and Bassin Flamant.

Two accounts of capture have been recorded (summarised in Table 1). Bat 2 appears to be the specimen of *Triaenops furculus* preserved in the British Museum (Natural History) (BM 78.185).

MICHAEL BETTS identified a small bat (approx. 5cm length) at the station as the tomb bat (*Taphozous mauritanus*) in 1998. It was identified from a photo found in the library of a bat taken from Nowark & Paradiso elsewhere. Identified using colour patterns and basic morphological traits of a live bat in the top of a coconut palm at 27x magnification binoculars.

In addition a bat was collected in a house at Picard on 9th April 2004. This was identified as *Triaenops furculus* by R. & G. GERLACH, the specimen is preserved in the collection of the Nature Protection Trust of Seychelles.

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A possible high-altitude roost of Seychelles sheath-tailed bats *Coleura seychellensis*

NICHOLAS BALL

'Russets', The Street, Old Basing, Basingtoke,
Hampshire, RG24 7BY, UK
[nickhyaena@btinternet.com]

As one of the most endangered mammals in the world, the Seychelles sheath-tailed bat *Coleura seychellensis* PETERS, 1868 is, as far as is known, struggling in terms of numbers. To date there have been only 32 individuals recorded. This figure has been collated by visual observations at a single cave on the granitic island of Silhouette, Seychelles. Within the order Chiroptera (bats) the family Emballonuridae, includes sac-winged bats, sheath-tailed bats and ghost bats. Sheath-tailed bats can be further divided into two genera with *Coleura* being African and Arabian sheath-tailed bats, and *Emballonura* being Old World sheath-tailed bats. Until relatively recently, *Coleura seychellensis* had not been researched and very little was known. The bats are small, only 55–65mm in length with a wingspan of 45–56mm in length and weighing of 10.2 grams in adult males and 11.1 grams in females (NICOLL & SUTTIE 1982). Vocalisation is in both ultrasonic frequencies and frequencies audible to human ears. The ultrasonic sounds are between the ranges of about 20kHz and to a max of 50kHz but usually around 30kHz when flying within the roost.

With a large area to cover, the best possible and most systematic technique to use to search for a new roost is that of transects. Initially an overgrown and disused path was used as a transect line. This was covered with a bat detector (Pettersson D-100) every night at around 6.30 for 6 nights for around 40 minutes.

The main path from Grand Barbe to La Passe was used as a second transect line. It was suitable as it was longer and went through many boulder fields with changing habitats. This second transect line was covered with a bat detector extensively during the day, during dusk and nightfall for 5 days and 3 nights. The bat detector was switched on regularly at points along the path that looked suitable for bat roosts. Large granite boulders forming caves would determine these 'suitable points'. These caves were extremely regular along the transect line, which meant the bat detector was on cumulatively for a long time. Each point would receive between 5 and 10 minutes of 'detector time' daily, usually differing in the time of day. As well as detecting from the path, transect lines at 45° from the path were used when cave systems were extensive and went back away from the path, or if a likely boulder formation was spotted from the path. These were usually at a distance of between 30 and 50 metres.

Upon detection of a frequency between 20kHz and 50kHz, the area was extensively explored and mapped. Droppings, if any, were to be collected along with recordings of temperatures and percentage humidity from both inside and outside the cave. Canopy coverage, a map of cave and vocalisation periods were also to be recorded from

the assumed roost site. Deciding upon the area the sounds were coming from was fairly straightforward as the range of the detector was limited, to no more than 10 or 15 metres. Not only is range of the detector limited, the directional range is around 120° (DOWNES 1982).

Vocalisations were recorded on the second transect line on several occasions. These vocalisations were almost certainly coming from a cave close by within a substantial cave system. To the human ear they were audibly identical to those recorded at the bat roost at La Passe. For example, the frequency detected by the detector was the same as that at the La Passe roost almost to within 1kHz, the pulsing was the same, and the timings in which they were heard were very similar.

The first vocalisations were first detected during the day at around 1.00pm. These were very clear and lasted for about 5 minutes. A return visit was made again that evening and, as expected, there was vocalisation around 6.30, which was the time in which the La Passe bats vocalised before emerging. This vocalisation, differing in both lengths and clarity, continued to around 7.05pm. At this time, vocalisation ended very abruptly and was not heard for the following hours spent outside the cave that evening.

Recordings were made for the next three days and evenings and showed very similar findings to that of the first day. There were vocalisations from the cave on days two and four but these were very minimal compared to those recorded on the first day. On day three there were no vocalisations heard during the day. Recordings were heard every evening around the same time of 6.30pm and ended abruptly at around 7.00pm, the same as the recordings on the first night. At around 6.45pm on night two the detector picked up some vocalisations that sounded like several bats squabbling. This lasted for between 5 and 10 seconds and was at the frequency of just over 30kHz.



Fig. 1 Entrance of the possible new roost

The cave was situated at a considerable height compared to the cave at La Passe. The cave was situated in a large granite boulder field near Gratte Fesse (515m) and was a 1.5-hour walk with equipment from Grande Barbe. The cave was surrounded by foliage of medium to high density with a canopy cover in the region of 80%. Foliage noted around the cave was typical to that of the whole island, with a few invasive species similar to that of the La Passe roost. There were many endemic palms such as *Nephrolepis vanhouet-*

teanum, which grew in front of the cave, plus ferns such as the 'bird nest fern' *Asplenium nidus* that grew over the top of one of the cave entrances. A large majority of the foliage was that of the introduced cinnamon tree, *Cinnamomum verum*. A plant covering the area in front of the entrance was *Clidemia hirta*, another introduced. This is a very invasive plant that spreads easily on the rainforest floor (GERLACH 1993). To the left and right of the cave grew *Angiopteris evecta*, an indigenous fern to the Seychelles. Growing to a fair height on top of the cave was *Dracaena reflexa*, which, like the palms, is endemic.

The cave was reasonably dark inside, with one main opening about 1×2m, plus several smaller openings positioned high towards the back of the cave, no larger than

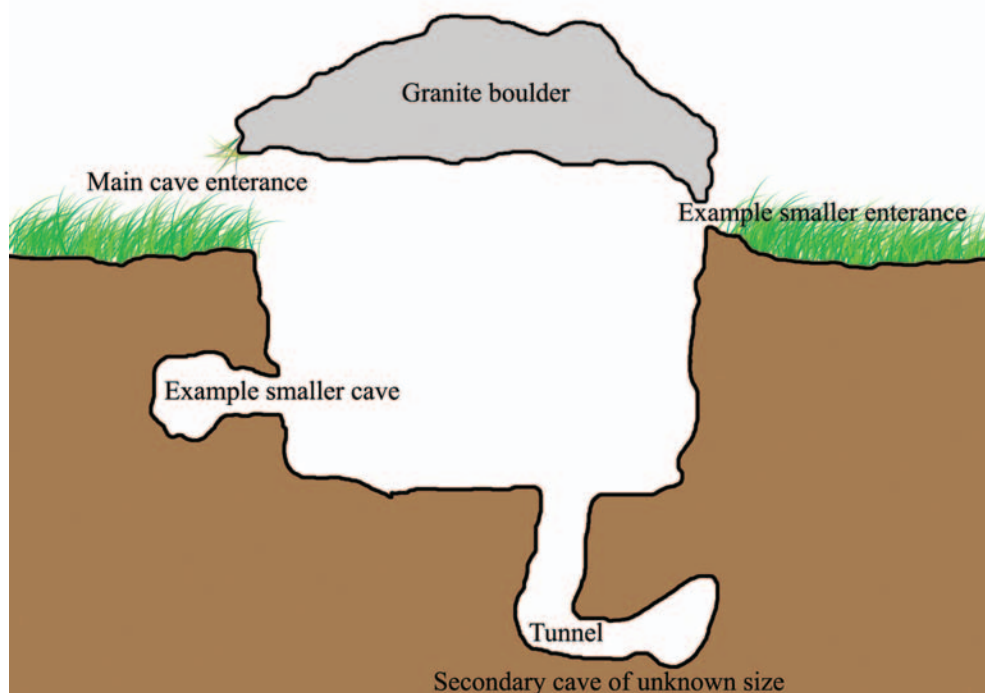


Fig. 2 Sketch of the possible roost

0.6×0.6m. Around the lower part of the cave were narrow passages leading to smaller caves, which were no larger than about 2×2m. The main part of the cave was around 5×6m with a ceiling height of about 4m. There were no bats visible in this part. On the floor of the cave was a vertical tunnel of about 2.5m deep with a diameter of around 1 metre. Upon illumination, the tunnel revealed a second chamber with an estimated ceiling height of over 1m. Size is unknown as access was not possible. As this second cave was underground, it felt substantially cooler although measurements were not taken. Table 1. summarises climatic data recorded at the roost described above and that of the roost at La Passe. As described by BURGESS & LEE (2004), the La Passe roost was in a field of eroded granite boulders situated in a forest of native and introduced flora. This description

	Possible new Roost	*La Passe Roost (two adjoining caves)
Temperature outside roost during the day (oC)	26-27	26-34
Temperature inside roost during the day (oC)	26-27	A: 27-31& B: 26-30
Average humidity outside cave during the day (%)	92.00	-
Average humidity inside cave during the day (%)	92.67	-
Approximate altitude from sea level (m)	450-515	40
Direction of most prominent cave entrance	South south-east	North north-west

Table 1. Climatic data at bat roosts on Silhouette (*La Passe data from BURGESS & LEE, 2004)

matches that of the possible roost at Gratte Fesse, which also has neighbouring cinnamon trees and palms.

While insects communicate using ultrasonic frequencies picked up by the bat detector, it is highly unlikely that these frequencies would match the complexity of the bats or those recorded at the cave site. Not only is similar complexity unlikely, but based on observations from the La Passe roost, vocalisation timings are as expected for bats. A climax of vocalisation starting around 6.30pm leading to an abrupt ending of vocalisation at around 7.00pm suggests that the bat may have been getting ready to leave the cave followed by a group emergence.



Fig. 3. *Coleura seychellensis* in the La Passe roost (photo by N. BALL)

JOUBERT (1996) states that roosting bats are non-vocal unless disturbed. This statement can be challenged as recordings have been made at the La Passe roost during the day when the bats were undisturbed and in their roost. These vocalisations are thought to be ‘squabbling’ for roost positions and stated to be ‘a common theme amongst the bats’ (BURGESS & LEE 2004).

Even though there were no bats observed visually, recordings of vocalisation do indicate that this is indeed an area where bats roost and further work should be carried out in order to determine the exact location of the roost and the number of bats in there. The vertical tunnel within the cave was delicate and not suitable for access without climbing equipment. However a remote camera could be very useful to determine the size of the secondary cave and if there were bats present. The secondary cave could also have another exit as well as the tunnel. Factors such position, remoteness, cave complexity, terrain and

climate all contribute to making it a difficult area to survey. A camp outside or near the cave would be possible and would almost certainly produce good results as recordings could be made throughout the night and day plus increasing the chance of a visible observation.

These bats are undeniably rare and need protection but there are almost certainly more roosts on Silhouette as the island is full of boulder fields with caves ideal and remote enough for roosts similar to that of the La Passe.

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The application of genetic research to the conservation of fruit bats in the western Indian Ocean

JOHN O'BRIEN AND THOMAS J. HAYDEN

Mammal Research Group
University College Dublin, IRELAND.
[johnob@ucd.ie]

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INTRODUCTION

The use of genetic methodologies to answer conservation-related questions makes sense intuitively. DNA is the basic unit of evolutionary change and is moulded by processes that leave characteristic 'signatures' that can accumulate over time, thereby recording the evolutionary history of a species or population. Thus, we can use DNA as a tool to infer the historical perturbations that have impacted a species or population and explain their current distribution and genetic diversity. We can then use this information to predict the response of a species or population to future pressures such as environmental change, habitat loss and population decline (LOESCHCKE *et al.* 1994).

Why is fruit bat conservation an issue?

Fruit bats of the genus *Pteropus* (Megachiroptera: Pteropodidae) are distributed from the Western Indian Ocean islands, eastward to the mid-Pacific islands in primarily tropical or sub-tropical climates (MICKLEBURGH *et al.* 1992). They act as important contributors to ecosystem maintenance, particularly on islands, through their role as seed dispersers and pollinators (FUJITA & TUTTLE 1991). Worryingly, island faunas are the most prone to extinction (ALCOVER *et al.* 1998) and 86% of *Pteropus* species inhabit islands (RAINEY & PIERSON 1992).

The most significant threats to fruit bats are habitat alteration, hunting and cyclonic storms that reduce populations and destroy food and roost trees (ROBERTSON 1992). There is a real need to investigate the viability of island populations of fruit bats in terms of extinction risk. Three of the seven extant species in the Western Indian Ocean are considered vulnerable (MICKLEBURGH *et al.* 2002) and are listed in the IUCN Red List (2003) [*P. rodricensis* (DOBSON 1878) from Rodrigues Island, *P. livingstonii* (GRAY 1866) from the Comoro Islands and *P. voeltzkowi* (MATSCHIE 1909) from Pemba Island].

There is a paucity of genetic research on bats. The order accounts for approximately one quarter of known mammalian diversity (NIKAIDO *et al.* 2000), but only 0.02% of DNA sequences accessioned under Mammalia in the DNA Sequence Databank (<http://www.ncbi.nlm.nih.gov/Genbank/>) are Chiropteran. In general fruit bats are a difficult group to study using standard observational techniques – they are highly mobile, nocturnal, have very fluid social systems and may form aggregations numbering thousands. In many cases parentage analysis is almost impossible using behavioural estimates due to

multiple mating. Genetic analysis can overcome many of these problems and its potential role in the conservation of fruit bats is becoming recognised.



Fig. 1. Distribution of *Pteropus* species in the western Indian Ocean: Seychelles – *P. s. seychellensis*; Aldabra – *P. (s.) aldabrensis*; Comoro I. – *P. (s.) comorensis* and *P. livingstonii*; Mayotte – *P. (s.) comorensis*; Pemba – *P. voeltzkowi*; Madagascar – *P. rufus*; Mauritius & Réunion – *P. niger*; Rodrigues – *P. rodricensis*

What is conservation genetics?

Conservation genetics can operate at two broad and often overlapping levels: between species (species-level) and within species (population-level).

Species-level studies.— One of the most fundamental units for conservation biologists is the ‘species’. However, what constitutes a ‘species’ is difficult to define as evidenced by the number of species concepts that are currently in existence (Wayne *et al.* 1994). Phylogenetics (defining species on the basis of genetic divergence) has proven to be of importance to conservation biology (AVISE 1996). There are numerous examples of cryptic species that are morphologically very similar but very different in genetic terms e.g. the existence of two species of European Pipistrelle bats (*Pipistrellus pipistrellus* spp.) with different echolocation frequencies was proven using genetic analysis (BARRATT *et al.* 1997). Thus, genetic analysis has a significant role to play in evaluating biodiversity.

Hybridisation has important implications for conservation management and allocation of limited resources. For example, the Ethiopian wolf (*Canis simiensis* RÜPPELL 1835) is the

most endangered of all canids. However, plans for an intensive breeding programme are hampered by difficulties in finding purebred animals due to introgression of dog (*Canis familiaris*) DNA (GOTTELLI *et al.* 1994). Some sympatric species of fruit bats are known to hybridise in overlapping parts of their respective ranges (MCWILLIAM 1985) and management plans should take this into account.

Phylogeography is the study of the relationship between species and their geographic distribution. By identifying the origins of species and subsequent dispersal or colonisation using genetic analysis, it is possible to put speciation processes in a geographic context. This facilitates the differentiation between dispersal and vicariance in a species history and is relevant to contemporary genetic variability (AVISE 1987). ANDERSEN (1912) admitted that his morphological taxonomy of fruit bats was hard to reconcile with their geographic distribution, and a genetic approach may prove useful in resolving this problem.

Population-level studies.— The comparison of genetic variability between populations is important for both *in situ* and *ex situ* conservation (BALLOU *et al.* 1995). In terms of wild populations, the impact of founder effects, genetic drift, gene flow and bottlenecks on variability are important questions. For captive populations, inbreeding and outbreeding are major concerns.

Range expansion or island colonisation by a species results in a founder effect since the initial colonisers generally represent a fraction of the genetic variability of the source population (also a factor in the establishment of captive populations as has occurred for three Western Indian Ocean fruit bats: *P. rodricensis*, *P. livingstonii* and *P. voeltzkowi*). If this founder population becomes isolated, random genetic drift will lead to further divergence. The extent of divergence will be determined by gene flow (SLATKIN 1994). If regular gene flow through mating occurs between meta-populations, they will tend to follow the same evolutionary trajectory. However, if it is absent, populations tend to evolve independently, potentially leading to speciation events

Any population that has been significantly reduced in number can be considered to have gone through a bottleneck. Rodrigues fruit bats (*P. rodricensis*) have suffered a number of population crashes with numbers as few as 70 individuals in 1974 making them, at the time, the world's most endangered bat (CHEKE & DAHL 1981). The implications of a bottleneck event will depend on a number of demographic traits but species with long generation lengths, low reproductive output and a skew in mating opportunities, as is typical of fruit bats, tend to suffer from eroded variability (LUIKART *et al.* 1998).

In instances where a bottlenecked population remains small (as might be the case in a captive population), the risk of inbreeding increases. Defined as mating between genetically similar individuals, inbreeding tends to reduce heterozygosity (a measure of genetic variability) and increases the likelihood of the expression of recessive lethal genes. Evidence is accruing for the negative impact of inbreeding on 'fitness' in terms of reproductive success and offspring survival (KELLER & WALLER 2002) and ultimately, extinction risk. However, breeding between genetically dissimilar populations can also have negative effects. This outbreeding tends to disrupt co-adapted gene complexes that may be important evolutionary adaptations to the local environment (ZSCHOKKE & BAUR 2002). The result is that both populations may suffer lower overall 'fitness'. Thus, replenishing a depleted population from another geographic area without considering their genetic relat-

edness can be detrimental.

How can conservation genetics be applied to fruit bats?

BURLAND & WORTHINGTON-WILMER (2001) recognised the value that molecular studies could play in answering some of the conservation issues faced by bats. The contribution of genetic research to conservation management is growing and no doubt will prove to be a vital element in the sustainability of island populations of fruit bats throughout their range. Most studies of *Pteropus* spp. fruit bats have concentrated on the Australasian region, the proposed region of origin for the genus (BERGMANS 1997) and the species from the Western Indian Ocean are under-represented in the literature. Our research is attempting to address some of this imbalance.

We have three main areas of interest that can be expressed in terms of conservation-related questions:

1. What are the genetic relationships between the seven extant and one recently extinct species of *Pteropus* fruit bat in the Western Indian Ocean?
In collaboration with colleagues in Yale University, USA, we are analysing the DNA sequences from four genetic loci in an effort to infer the colonisation patterns and degree of divergence between purported species. From this we can determine the evolutionary history of the species in this geographic region. This kind of information is useful to conservation managers by identifying taxonomic and management units. Preliminary results suggest a complex colonisation process with possibly three separate colonisation events beginning about one and a half million years ago. As more species are added to the phylogenetic tree and compared to the phylogenies produced from other genetic loci, the pattern of speciation in the Western Indian Ocean archipelagos will become clearer.
2. How has recent population declines impacted the genetic diversity of Rodrigues fruit bats (*Pteropus rodricensis*) and how effective is the captive breeding programme in retaining wild-type genetic variability?
In collaboration with the University of Tennessee, USA, we are analysing the genetic diversity of the wild population of fruit bats on Rodrigues Island and comparing it to a captive population at Dublin Zoo in Ireland. Using microsatellite (small repeated fragments of DNA) analysis, we have found relatively low but equivalent variability in both wild and captive populations. Our results to date suggest that the species has retained some genetic diversity despite being reduced to less than 70 individuals in the early 1970's – a significant population bottleneck. The biggest threat to the captive breeding programme may be genetic drift, indicated by some divergence between the captive and wild populations. Further microsatellite loci are being tested to clarify the pattern of variability.
3. What are the genetic relationships between island populations of *Pteropus seychellensis* and how can this data be used to formulate a conservation management plan?
There are three sub-species of *P. seychellensis* (MILNE-EDWARDS, 1878) currently recognised (HILL 1971) – *P. s. seychellensis* on the granitic islands of the Sey-

chelles; *P. s. aldabrensis* on Aldabra Island and *P. s. comorensis* on the Comoro Islands. The degree of genetic divergence between these subspecies is unknown and their geographic isolation may provide an argument for incipient speciation processes. In collaboration with the Nature Preservation Trust Seychelles, Seychelles Island Foundation and Yale University, we hope to investigate the genetic variability of island populations of this subspecies complex and to identify management units using microsatellites. Furthermore, we hope to determine the extent of gene flow within island groups with a view to elucidating population substructure. Sampling is underway on the relevant islands and DNA analysis will begin shortly on this element of our research.

CONCLUSION

Genetic research contributes to conservation by evaluating biodiversity, acting as a tool to understanding the evolutionary history of species and populations, and providing information useful for risk assessment in terms of sustainability at various hierarchical levels. Our current research project is a timely genetic analysis of the fruit bats of the Western Indian Ocean given their vulnerability as endemic faunas in highly threatened biodiversity hotspots.

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Bats as bushmeat: a survey by Fauna & Flora International

KERRY WAYLEN

Bats as bushmeat project coordinator

Fauna & Flora International, Great Eastern House, Tenison Road,
Cambridge CB1 2TT, UK

[Kerry.Waylen@fauna-flora.org]

The consumption and trade of bushmeat is considered a significant conservation issue in many parts of the world (Robinson & BENNETT 2000) with attention usually focused on larger species, especially primates (e.g. BOWEN-JONES & PENDRY 1999). However, in some areas there has been growing concern about the potential impact of the bushmeat industry on bats: for example on the Pacific island of Guam, hunting is officially recognised as the chief cause of the decline of the Marianas flying fox *Pteropus mariannus*, Desmarest, 1822 (MICKLEBURGH 2002). Despite the potential problems that bushmeat consumption may evidently pose, there has been no overall global view on the impacts on bats from their use as bushmeat.



Fauna & Flora International (FFI) is undertaking a preliminary survey of the use of bats as bush meat to assess the scale of the problem and identify where issues relating to trade and hunting need to be addressed. Having identified any priority areas, FFI will then fundraise for projects that will be undertaken as part of FFI's Global Bat Conservation Programme. FFI is the world's longest established international conservation body, and acts to conserve threatened species and ecosystems worldwide, choosing solutions that are sustainable, are based on sound science and take account of human needs. Further information about FFI's wider aims and activities can be found at www.fauna-flora.org.

Whilst some regions of the world report negligible bat consumption, preliminary information from the Western Indian Ocean suggests that this is a region where bat consumption is relatively common. For example, there have been several reports from the Comoros that bats are eaten, but many consider this to have no significant impact on bat populations. This may also be the case in the Seychelles. However, in the Mascarenes the impact of hunting on the Rodrigues flying fox *Pteropus rodricensis* Dobson, 1878, is relatively well recognized, and local hunting is known to have played a part in the decline of some other species. For example, both deforestation and hunting are thought to have contributed to the extinction of the dark flying fox, *Pteropus subniger* KERR, 1972 in the late 19th Century.

FFI is seeking your cooperation with this preliminary survey and is asking that you spend a short time filling out a questionnaire (see below for link). Every piece of information about hunting and trade in bats is useful, even if it is just to say that there is no evidence that bats are used in these ways. Specialist knowledge is not necessarily required. When you have completed the questionnaire please e-mail it back to the address below by the 30th September. It would also be extremely useful if you could pass on the details of this

investigation to any other individuals who might be able to help. If you are interested in developing collaborative projects on research into hunting and trade in bats please contact SIMON MICKLEBURGH at FFI [simon.mickleburgh@fauna-flora.org] to discuss this further.

The questionnaire may be obtained from the website of the Sustainable Use Specialist Group of IUCN, http://www.iucn.org/themes/ssc/susg/bushmeat_bats_questionnaire.doc, and the project coordinator is able to provide the questionnaire in French.

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On the diet of an anthropophilic population of Seychelles tree frog *Tachycnemis seychellensis* (Hyperoliidae)

J. GERLACH¹ & G. ROCAMORA²

¹133 Cherry Hinton Road, Cambridge CB1 7BX, UK
[jstgerlach@aol.com]

²Island Conservation Society
PO Box 775, Mahé, SEYCHELLES
[ics@seychelles.sc]

The Seychelles tree frog *Tachycnemis seychellensis* (GUNTHER, 1868) has been the subject of taxonomic and phylogenetic studies but little is know of its ecology. Reproductive biology was briefly described by NUSSBAUM (1984) and an account of foraging behaviour and home ranges has recently been published (ROCAMORA 2003). Here we present the results of dietary analysis from the population used for this latter study.

On 4th September 2003 16 faecal samples were collected from a bathroom in a house at 390m a.s.l. at Fairview, La Misère on Mahé. These were rehydrated and dissected under a stereo dissecting microscope at ×20 magnification. The results of the dissections are summarised in Table 1.

Table 1. Contents of Seychelles tree frog faeces

Item		Number		Percentage	
		faeces	items	faeces	items
Cockroach	? <i>Pycnoscelus indicus</i>	4	4	25	21
	? <i>Lobopterella dimidiatipes</i>	1	1	6	5
Moth		5	6	31	32
Bush cricket		1	1	6	5
Ant	<i>Technomyrmex albipes</i> (alate males)	1	3	6	16
Earwig	<i>Chelsioches morio</i>	2	2	13	11
Unidentified		2	>2	13	11

The most important dietary components of these small samples were moths and cockroaches (in terms of both number of individuals and of faeces). Visual observation suggests that these are the most abundant large insects to be attracted to lights, although the house had been uninhabited for two months. It is probable that the samples here represent non-selective feeding on the white interior walls of the house where these frogs used to hunt at night and where the faeces were collected. This provides some indication of a lack of selectivity in the tree frog diet. However, these samples were taken from a highly un-

natural location and may not be representative of the natural diet of Seychelles tree frog. These results also highlight the positive role of the tree frogs in helping to control insects populations around human habitations. Frogs leaving in residential areas are probably very vulnerable to poisoning through ingestion of insects contaminated by pest control treatments, that have become common in and around many houses.

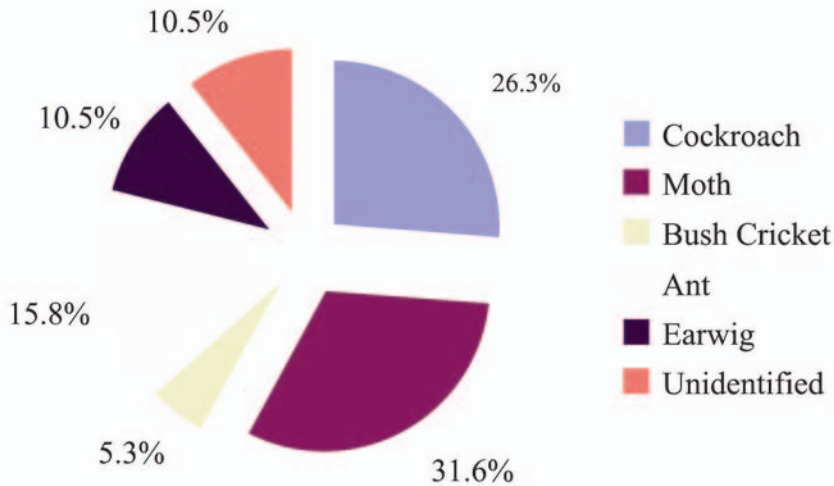


Fig. 1. Percentages of different prey items eaten by Seychelles treefrogs.

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A record of *Phelsuma astriata astriata* on Praslin Island

GUY VAN HEYGEN

Mechelsesteenweg 229, 2860 Sint Katelijne Waver, Belgium
[guy@vanheygen.com]



Fig.1 *Phelsuma astriata astriata*

The distribution range of *Phelsuma astriata astriata* (Fig.1) is limited to Mahé including some of its offshore islets and Silhouette. The status of the Fregate population is uncertain as it has various morphological differences with the nominate form and the subspecies *P. astriata semicarinata*. (E. VAN HEYGEN *pers. comm.* & A.S. CHEKE 1982). Another population of *P. astriata astriata* occurs on the Astove atoll and was originally described as *Phelsuma astovei* (FITZSIMONS, 1948), but was later considered as a subspecies of *P. astriata* (MERTENS 1962) and finally the same as the nominate (GARDNER 1987). On Praslin however, only a subspecies occurs, *P. astriata semicarinata*. The distribution range of this subspecies is generally limited to the northern granitic islands of the Seychelles. More specifically Praslin and La Digue, and their various satellite islands including Aride, Felecité, Little Sister, Big Sister, Marianne, Curieuse, Cousin and Cousine. Other populations are more recently established on the coralline islands Denis (HALLMANN *et al.* 1997) and the Amirante islands of D'arros and St. Joseph (CHEKE 1982).

In June 2004 a *P. astriata astriata* male was observed near Bay Sainte Anne, Praslin, on a banana tree patch about 500 m from the jetty and shared its territory with several female *P. astriata semicarinata* and a for the genus *Phelsuma* typical social group and hierarchy seemed to have been established. It is uncertain whether the group reproduces but a gravid female of *P. astriata semicarinata* was also captured. This animal can have been fertilized however by another male of the same subspecies.

At this point we can not claim that *P. astriata astriata* has an established population on

Praslin since no typical females have been located. It is unlikely that such a population will easily establish itself since *P. astriata astriata* and *P. astriata semicarinata* inhabit the same ecological niches in their distribution ranges. On Praslin, *P. astriata semicarinata* also has to share its territory with much larger *P. sundbergi sundbergi* whereas the preferred habitat of *P. astriata astriata* and *P. sundbergi longinsulae* on Mahé and Silhouette only partly overlap. The “*astriata*”-population on Fregate is much more vulnerable for alien *Phelsuma* species or subspecies since the animals are much smaller and only partly share their habitat with *P. sundbergi longinsulae*.

It has been proven that *Phelsuma* species easily establish on lands where there is little or no competition. Recent examples are *P. madagascariensis* in Florida (KRYSKO, HOOPER & SHEEHY 2003), *P. laticauda*, *P. guimbeaui* and *P. madagascariensis* in Hawaii (KISHINAMI & KISHINAMI, 1996 and KRAUS 2002), *P. sundbergi sundbergi* on Desroches (BUDZINSKI 2000) and *P. astriata astriata* on Alphonse (GLASNER, pers. comm.)

The first record of *P. sundbergi* population on Desroches was only noted after the only hotel on the Island was renovated and the record form *P. astriata astriata* on Alphonse dates right after a hotel was built on the atoll.

The record of *P. astriata astriata* on Praslin, so close to the jetty, implies that the specimens probably arrived here by boat from Mahé with building or other material.

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Ecology and biology of a Seychelles island *Borbo gemella* (Lepidoptera: Hesperinae) metapopulation

JAMES M. LAWRENCE

21 Venus Street, Atlasville, 1459, SOUTH AFRICA
[davlaw@mweb.co.za; zizeeria@hotmail.com]

INTRODUCTION

Borbo gemella (Mabille) is widespread throughout Africa (ACKERY, *et al.* 1995). Within Seychelles, it has been recorded from the islands of Mahé (BERGER 1962; FLETCHER 1910; FRYER 1912; JOANNIS 1894; LEGRAND 1965), Silhouette (Berger 1962; Fryer 1912; GERLACH, *et al.* 1997); Praslin (BERGER 1962; Fletcher 1910; Fryer 1912; JOANNIS 1894), Aride (Aride Island Research Group 1999), Coetivy (LEGRAND 1965), Alphonse (FLETCHER 1910; HOLLAND 1895); Platte (HOLLAND 1895) and Aldabra (LEGRAND 1965). Only recently has *B. gemella* being recorded from Cousine Island (LAWRENCE, *in prep.*).

Although many observations on this species have been made from Continental individuals, very little information, except for distributional records, have been made on an island population of this species. In response, this article will focus on the following aspects of the ecology and biology of *B. gemella* on Cousine Island, Seychelles: 1) biotope selection; 2) influence of rainfall on abundance and phenology; 3) activity times; 4) nectar sources and larval food plant selection.

Site

Cousine is a small granitic island situated 4° 20' 41" S and 55° 38' 44" E (Fig. 1a). It is just over 1km long, 400m at its widest point and 27ha in area (BOURQUIN 1997). The highest point on Cousine is approximately 70m a.m.s.l.. The Seychelles islands experience a humid, tropical climate as defined by TRICART (1972), in that mean monthly temperatures are generally above 20°C and annual rainfall exceeds 700-800mm. Although the climate is seasonal, the summer NW monsoon (i.e. December to March) brings a higher rainfall than the winter SE trade winds (i.e. May to October). The transition months of April and November generally experience high rainfall (WALSH 1984). Relative humidity varies little throughout the year averaging 77% (IYER & FRANCIS 1941).

Topographically, Cousine consists of two hills separated by a saddle, and a coastal flat on the northern and eastern sides of the island (Fig. 1b). The vegetation of the hilly region consists mostly of undisturbed forest dominated by *Euphorbia pyrifolia* Lam., *Ficus reflexa* Thunb., *F. lutea* Val., *Pisonia grandis* R.Br. and *Pandanus balfouri* Mart. trees. *Ipomoea pescaprae* (L.) R.Br. herblands, mowed grass areas (dominated by *Cynodon dactylon* (L.) Pers. and *Stenotaphrum dimidiatum* (L.) Brongn.), and a secondary herbland/woodland dominate the coastal flat.

Over the last several years the coastal area has undergone an extensive rehabilitation programme (HITCHINS 1999). Large areas of *Ipomoea pescaprae* (L.) R.Br. and various alien and/or invasive species, such as *Stachytarpheta jamaicensis* (L.) Vahl, *Amaranthus dubius* Mart. Ex Thell, *Achyranthes aspera* L., *Datura metel* L., *Carica papaya* L. and *Asystasia* sp. are being removed or kept under control. Although it is unclear what the original vegetation of the coastal flat was, remnants of *P. grandis* forest on the northern section of the coastal flat indicate that forest used to occupy the coastal flat (BOURQUIN 1997). As a result, large numbers of indigenous trees have been planted in this area.

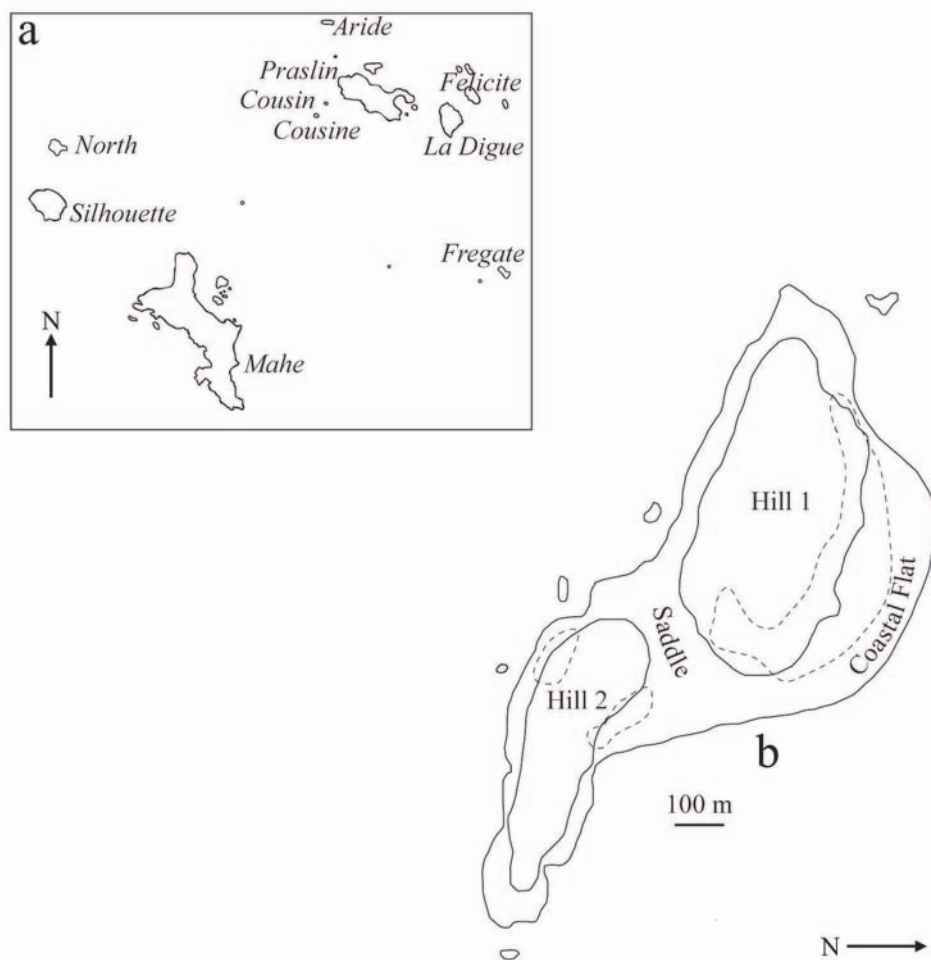


Fig. 1 (a) The main central group of granitic islands of Seychelles, showing the position of the study island, Cousine. (b) General meso-distribution of *Borbo gemella* on Cousine, Seychelles. Areas in which the butterflies occurred are enclosed by dashed lines

METHODS

On Cousine, data were collected between 5 June 2002 and 3 May 2003, between 06h00 and 18h00. The location on the island of all individuals seen was recorded. Also, the time each individual was first seen was noted. Four time periods were quantified, each three hours long, between 06h00 and 18h00.

The biotope in which each individual was sighted was recorded. Three biotopes, each differing in vegetation heterogeneity and complexity were defined: 1) forest biotope: areas densely covered with trees taller than $\pm 5\text{m}$; 2) open biotope: areas dominated by grasses and/or herbs, due to the habitat rehabilitation programme on the coastal flat, young trees (less than 5m in height) sparsely covered portions of this area; 3) forest edge biotope: an ecotone area consisting of the forest and open biotopes.

The food source of all feeding individuals was noted. Also, all oviposition observations were recorded. All botanical names and authorities follow ROBERTSON (1989). As *B. gemella* was not commonly encountered, abundance was measured as the total number of individuals seen per month. Daily rainfall was measured using a standard rain gauge.

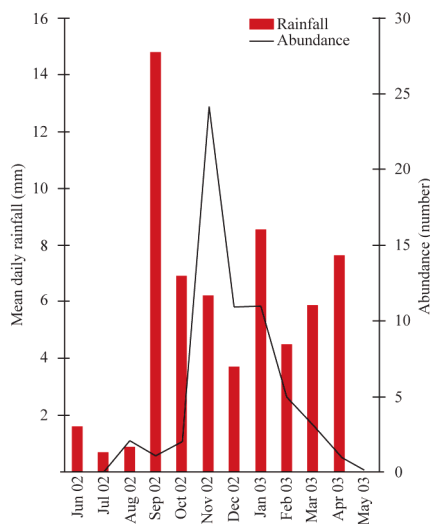


Fig. 2 *Borbo gemella* abundance and mean daily rainfall per month (mm) between June 2002 and April 2003. No butterfly or rainfall data were collected during May 2003

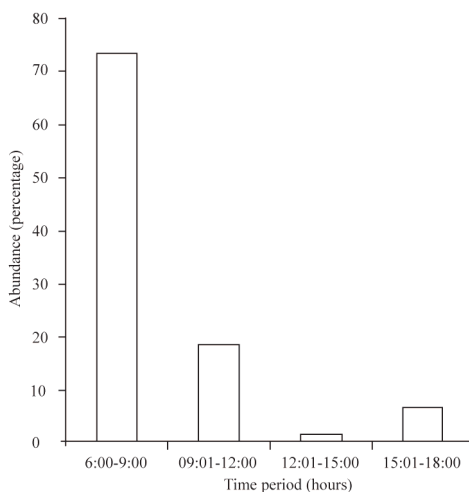


Fig. 3 The percentage abundance of *Borbo gemella* observations per three-hour time period between 06h00 and 18h00

RESULTS

A total of 60 butterfly observations were made on Cousine. Most butterfly observations (i.e. 76.7%) were made in the 'forest edge biotope'. Few butterflies were seen in the 'open biotope' (i.e. 10.0%) and the 'forest biotope' (i.e. 13.3%). The general meso-distribution of *B. gemella* on Cousine is shown in Fig. 1b.

On Cousine, butterflies were encountered during all months of the study period, except June and July (Fig. 2). However, no data were collected for May. Seventy-six per-

cent of all observations were made between November and January, with the most observations made during November (i.e. 24 observations). Adults were generally seen during the wetter months (i.e. NW monsoon) with very few observed during the drier months (i.e. SE trade winds) (Fig. 2). Individuals were most frequently seen during the early morning (i.e. between 06h00 and 09h00), with 73.3% of all observations made during this time of day (Fig. 3). Butterflies were rarely seen during other times of the day.

Eleven feeding observations were made. The following flower nectar sources were used: *Asystasia* sp. (one observation); *Catharanthus roseus* (L.) G.Don (three observations), and *Turnera ulmifolia* L. (seven observations). All feeding observations were made on the coastal flat area.

Three oviposition observations were made between 6 January 2003 and 17 January 2003. In all cases, a single egg was laid towards the end of the upper surface of young *S. dimidiatum* grass swards. All oviposition observations were made on the coastal flat area.

DISCUSSION

Vegetation type clearly affects the meso-distribution of *B. gemella* on Cousine, with butterflies preferring the forest edge biotope. *B. gemella*, nevertheless, displays a high degree of ecological tolerance, with individuals encountered in both the forest and open coastal flat areas. Interestingly, numerous individuals were seen in disturbed vegetation around Grande Anse, Praslin (± 10 m a.m.s.l.) on the 19 October 2002. This wide ecological tolerance is also found in the continental African individuals, as it has been recorded from savannah, bushveld and rainforest habitats (HENNING, *et al.* 1997).

On Cousine, the main flight period (i.e. November to January) coincides with the wetter months of the year. The only months in which it was not recorded were June and July. Although no data were collected for May, it most likely would be scarce during this month, particularly as May is generally a dry month. In southern Africa this species has been recorded throughout the year, with March and April being when it is most frequently encountered (HENNING *et al.* 1997).

Short visits to Beau Vallon, Mahe (± 200 m a.m.s.l.) on the 3 June 2002, and to Plaine Hollandaise, Praslin (± 150 m a.m.s.l.) on the 29 August 2002 showed that *B. gemella* was relatively abundant on these larger islands. Interestingly, *B. gemella* was scarce on Cousine during this period. Possibly the greater rainfall on the larger, higher islands compared to the smaller low-lying islands (WALSH 1984) allowed the adults to be present during the lower rainfall period of the SE tradewinds. Adults were most active during the early morning period between 06h00 and 09h00. This period was the coolest part of the day. It is well known, particularly in tropical areas, that butterfly activity is suppressed by high temperatures (OWEN 1971). Many of the individuals observed in the early morning were seen perching with the hind wings fully expanded, and the forewings held half-open, possibly to aid thermoregulation (CLENCH 1966).

The flowers of three plant species were used as nectar feeding sources for *B. gemella*. As these nectar species were absent from, or rarely encountered in the forested areas, all the feeding observations were confined to the coastal flat area. Clearly, *T. ulmifolia* was the preferred nectar source. Several individuals were also observed feeding from the flowers of *T. ulmifolia* on Praslin at Plaine Hollandaise (29 August 2002). As *T. ulmifolia* and *C. roseus* are considered non-indigenous to Seychelles (J. GERLACH, *pers. comm.*), it appears as though *B. gemella* prefers exotic plants for nectar sources. Whether

Asystasia sp. is native or not will depend on its final identification (Gerlach 1996).

Larvae of *B. gemella* have been recorded on many species of Poaceae (e.g. *Ehrharta* sp., *Triticum* sp., *Saccharum* sp. and *Zea* sp.) (LARSEN, 1996). Although the indigenous *S. dimidiatum* was the only Seychelles record for *B. gemella* at present, it is quite likely that it would also use other Poaceae species on Cousine. As *S. dimidiatum* is restricted to several patches on the coastal flat, all oviposition observations were obviously confined to these areas. Eggs are laid towards the end of the grass sward. Common practice on Cousine has been to cut most grass areas on the coastal flat. This could reduce the number of suitable breeding areas on Cousine. Whether or not this has a large impact on this species on Cousine is not known. However, leaving patches of *S. dimidiatum* uncut, especially near the forest edge could possibly benefit this species.

ACKNOWLEDGEMENTS

I would like to thank Mr. M.F. KEELEY of Cousine Island for the opportunity of making this study, Mr. J. HENWOOD for several data records and logistical support during the study, and Mr. G. HENNING for his help in confirming the identification of the species.

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Remarks on the *Phelsuma barbouri*— and *Phelsuma klemmeri*— phenetic groups, *Phelsuma* GRAY, 1825

EMMANUEL VAN HEYGEN
Winketkaai 16, 2800 Mechelen, Belgium
[emmanuel@vanheygen]

INTRODUCTION

LOVERIDGE (1942) made the first attempt to sort out relationships within the genus *Phelsuma*, neither groups were named nor was a phenetic key provided. In MERTENS's (1962) revision he slightly modified LOVERIDGE's (1942) characteristics and used them to designate species groups. GLAW & VENCES (1994) added and modified groups relevant to that date. For *Phelsuma klemmeri* and *Phelsuma barbouri* however, neither a group was named, nor were they assigned to any of the existing groups. In the latest revision, by GLAW *et. al* (1999), *Phelsuma klemmeri* was placed as a single taxon within the *P. klemmeri*-group and the in the mean time described *Phelsuma pronki* (SEIPP, 1994) was placed together with *Phelsuma barbouri* in the new *P. barbouri*-group.

Recently 4 other taxa were described, *Phelsuma hielscheri*, *Phelsuma kely*, *Phelsuma malamakibo* and *Phelsuma vanheygeni* (NUSSBAUM *et al.* 2000, ROESLER 2000 & LERNER 2004, of which only *P. kely* was designated to a existing species group; the *P. lineata*-group (SCHÖNECKER *et. al* 2004).

RESULTS & DISCUSSION

Described species since 1999.— *P. hielscheri* and *P. malamakibo* seem to be related to the *P. dubia*-group, but both have keeled ventralia. The morphological characteristics of *P. vanheygeni* did not allow it to be assigned to one of the existing species groups. A complete new revision is thus necessary and will be published separately.

Phelsuma barbouri-group.— GLAW *et. al* (1999) placed *P. barbouri* together with *P. pronki* in the *P. barbouri*-group based on two criteria; the fact that both species are egg gluers, and the “similarities” between the two species. New records of the reproduction of *P. pronki* however prove that this species lays its eggs and not glues them to a surface (R. GEBHARDT & H-P. BERGHOF, *pers. comm.*) as erroneously published by HENKEL & SCHMIDT (1995). Therefore I suggest to exclude *P. pronki* from the *P. barbouri*-group and leave *P. barbouri* as the only member of this group.

Phelsuma klemmeri-group.— GLAW *et. al* (1999) considered *P. klemmeri* as the only species within this group. The new data on the reproduction of *P. pronki*, egg laying in stead of egg gluing, and the similarities in habitus suggest a closer relation to *P. klemmeri*. Both species are dorsoventrally flattened and have one or more strongly enlarged lateral tubercle scales between the orbit and the forelimb. Other similarities are the smooth ventral and

dorsal scales, the uniformity in scalation and the divided subcaudalia, so there is little doubt about the close relationship of both species. *P. pronki* and *P. klemmeri* should form the *P. klemmeri*-group.

Current temporary status.— This status only consists of the typical Malagasy taxa and is only temporarily since *P. hielscheri*, *P. malamakibo* and *P. vanheygeni* can not be designated to any of the existing groups, making a complete revision necessary.

<i>P. barbouri</i> -group:	<i>P. barbouri</i>
<i>P. dubia</i> -group:	<i>P. berghofi</i> , <i>P. dubia</i> and <i>P. flavigularis</i>
<i>P. guttata</i> -group:	<i>P. abbotti</i> , <i>P. guttata</i> , <i>P. masohoala</i> and <i>P. seippi</i>
<i>P. laticauda</i> -group:	<i>P. antanosy</i> , <i>P. laticauda</i> and <i>P. serraticauda</i>
<i>P. lineata</i> -group:	<i>P. kely</i> , <i>P. lineata</i> , <i>P. pusilla</i> and <i>P. quadriocellata</i>
<i>P. madagascariensis</i> -group:	<i>P. madagascariensis</i> and <i>P. standingi</i>
<i>P. modesta</i> -group ¹ :	<i>P. modesta</i>
<i>P. mutabilis</i> -group:	<i>P. breviceps</i> and <i>P. mutabilis</i>
<i>P. klemmeri</i> -group:	<i>P. klemmeri</i> and <i>P. pronki</i>
Not assigned:	<i>P. hielscheri</i> , <i>P. malamakibo</i> and <i>P. vanheygeni</i>

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¹ *P. cepediana* is not a typical Malagasy taxon and is thus excluded